THE CREATIVE COGNITIVE PROFILES OF STUDENTS FROM DIFFERENT SOCIOECONOMIC ENVIRONMENTS

by

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Abstract

Creativity has been garnering increased attention in educational research and practice, so it is important to understand if there exist inequalities in student creativity as there are for other important educational outcomes. In order to investigate this in a tractable, non-deficit way, we argue that our analyses of socioeconomic status (SES) and creativity would be best conducted through an educational neurocognitive learner profile lens, seeking ways that students from different socioeconomic backgrounds might have relative strengths and similarities in cognitive abilities underlying creative behaviors. We analyzed student performance on a battery of cognitive measures assessing executive skills (working memory, inhibitory control, and shifting) and creative cognitive abilities (divergent thinking, insight, and associative processing) completed by 108 primary-aged students identified for their talent development potential. A series of stepwise regression models were estimated in order to examine relationships between these cognitive skills and guardian SES. Our results demonstrate the value of a learner profile framework: whereas higher SES students demonstrated relative advantages on measures of working memory, insight, and associative processing, student across the SES spectrum performed similarly on tasks assessing divergent thinking, shifting, and inhibitory control. We conclude by discussing implications of these findings for educational practice regarding talent development and research concerning both executive functioning and creativity.

Primary Reader and Advisor: Amy Shelton

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Preface and Acknowledgments

My desire to earn a doctorate degree long preceded even a vague understanding of the discipline in which I would focus this desire, but I knew I wanted to learn and research about something deeply. I loved studying the mind and reading about – at the time – cutting-edge neuroscience findings while completing my undergraduate philosophy work. Partly because of this, I thought teaching and education would be great foci for a career. Working with children each day as a fourth-grade classroom teacher was, indeed, some of the most enjoyable work of my life thus far. However, the serendipitous convergence of this passion for education and learning, and the introduction of a brand-new doctoral program at the Johns Hopkins School of Education provided the perfect catalyst for my doctoral desire.

With my foundational interests in education and the mind, as well as some awareness of the existence of an education-related discipline of educational cognitive neuroscience, I started my doctoral work in earnest looking for ways that I could marry my intellectual passions and contribute to this budding field. Also informing my doctoral studies was my experience with students socioeconomically very different from me in my elementary classroom. This led to my discovery of the social cognitive neuroscience field, in which cognitive scientists and neuroscientists have been analyzing the mind and brain in the context of childhood social circumstances. Again somewhat serendipitously, while exploring creativity research and talent development with the Center for Talented Youth (CTY) Research Lab, I started noticing overlap in the cognitive skills implicated in both of these seemingly disparate bodies of research. This is the genesis of the present work, and, for these reasons, I hope this work is informative for both teacher and researchers in multiple disciplines.

I want to recognize countless individuals and institutions for their role in this story. Faculty in the Philosophy Department at Loyola College in Maryland spurred my curiosity about the mind while helping me begin to sharpen my own, particularly in writing. Baltimore County Public Schools and the school at which I taught – Baltimore Highlands Elementary School – provided me a place to nurture my interests in education and challenge me daily to improve my understanding of teaching and what it means to learn at the most intimate level. I am particularly grateful to my principal, Brian Williams, for his

(reluctant) support during my first year of teaching and for his encouragement as I entered the doctoral program full-time.

At Johns Hopkins, I am grateful to the School of Education, the Center for the Social Organization of Schools, and CTY for all playing various roles in shaping my education research acumen. Specifically, Nettie Legters, Mariale Hardiman, Ranjini JohnBull, Bob Balfanz, and Richard Lofton have all enriched my understanding of education research while helping me progress through the program, providing practical outlets for what I was learning in the classroom. Peers from my inaugural PhD cohort and subsequent cohorts provided daily intellectual stimulation and friendly support.

I also want to thank the faculty members who directly supported my progress through the major program milestones. Specifically, Ranjini JohnBull, Mariale Hardiman, Lieny Jeon, Jonathan Plucker, Steven Gross, and Erica Sibinga. They have all provided incredibly detailed and supportive feedback on my dissertation research, helping to shape it into this final product, as well as in ways that may support publication of this research in the future. Perhaps equally as important, they all displayed a passion and enthusiasm for my ideas that motivated me to finish this work.

Talking through my first curiosities about this line of research, building a protocol to see it out, and attending to the sometimes monotonous day-to-day data collection required a team of peers that would selflessly invest in my work. These peers were various members of the CTY Lab: Joseph Santamaria, Ashley Flynn, Kinnari Atit, and Amy Stephens. I am in particularly large debt to Joseph and Ashley. Without both, we never would have reached the analytical sample size used here.

One other person at Hopkins falls into many of the aforementioned categories: Amy Shelton was my professor, helping me hone my statistical acumen; she has been present through each of my program milestones, from comprehensive exams to the present; she has spearheaded many of the discussions at the CTY Lab that have directly benefited my work; and, she has been a kind and generous advisor for the majority of my time at the School of Education, steering me through coursework, logistics, and ultimately towards this finished thesis.

Of course, while I am grateful to these individuals who supported my intellectual development over the past several years, another group has supported my entire development. I want to specifically thank my parents – Keith and Sandy Wrightson – for not questioning me (too much) when I left a lucrative career trajectory in the national defense industry to become a teacher, like my mother. The same goes for Edward and Shirley Adkins, my grandparents who have been a part of our nuclear family as long as I can remember; and also my other grandparents, who, unfortunately, are deceased – Rose and Thomas Wrightson.

Rose was the inspiration for my newborn daughter's middle name, Amelia *Rose* Wrightson. I'm thankful for the smiles and hope she's provided at the end of this journey (and hopefully she will forget – or never remember – the times the work has pulled me away from her). Finally, I'm deeply grateful to my wife, Nicole Wrightson. She is the reason why Baltimore Highlands Elementary plays such an important role in my story. It's where we met. Much like my parents years before, she also displayed patience, understanding, and unwavering support when I told her that I planned to abandon my already relatively low first-year teacher salary for a much lower graduate student stipend…for several years. I could not have finished this work without her.

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Introduction

Creativity has garnered increasing amounts of attention in educational research, policy and practice, as well as in other realms, such as business and economics. Though the roots of creativity research are generally traced back to the middle of the twentieth century, some have noted the more recent exponential growth of published research – particularly psychometric approaches to examining creativity (Plucker & Makel, 2010). Educational initiatives with broad support, such as the *Partnerships for 21st Century Learning* (www.p21.org), have highlighted creativity as an important skill to develop in students. Creativity has not historically been viewed as crucial in the K-12 mainstream American curriculum, but there are signs around the world that an emphasis on nurturing creative potential in students is growing (Beghetto, 2010; Makel, 2009; Smith & Smith, 2010). Simultaneously, there is a growing research interest in how best to develop and analyze creativity in classrooms (Beghetto, 2010; Delis et al., 2007; Freund & Holling, 2008; Gregory, Hardiman, Yarmolinskaya, Rinne, & Limb, 2013; Makel, 2009; Smith & Smith, 2010).

As creativity is increasingly recognized as an important capacity for human life in the twenty-first century, one that schools will undoubtedly be charged with developing in students, it is important to understand to what extent there might exist inequalities. As a society, we tend to accept *individual* differences in skills and abilities, but systematic, structural *group* differences or inequalities tend to be viewed less favorably. One specific dimension of inequality that has long been of concern to those in education and sociology concerns socioeconomic status (SES), because it predicts – time and again – numerous important life outcomes, such as physical health, access to educational opportunities, and career prospects (Bradley & Corwyn, 2002).

In education, differences among students according to their SES are of particular concern for at least two reasons. First, though there are numerous stated purposes for education, it is uncontroversial to suggest that education is perceived by many as a means for developing citizens for a well-functioning democracy, for economic well-being, and for a good quality of life. If certain groups are systematically disadvantaged in these respects, that should be concerning in and of itself. Second, such student SES differences are worrisome because these differences are thought to be – in large part – due to environmental disparities (Hackman, Farah, & Meaney, 2010). As opposed to heritable differences, the environmental inequalities associated with SES are more amenable to intervention. Indeed, one could argue for a moral, social justice imperative to intervene in order to ensure an equitable education system and society. Therefore, particularly in education, it is important to uncover inequalities amongst students based upon their SES and then intervene where possible.

Due to the abovementioned trends regarding creativity and education, it is important for education researchers to assess the degree to which this important twenty-first century skill is related to SES. If there is indeed an imperative to remedy educational inequalities, their existence must first be demonstrated. An obvious extension to the decades of SES-educational inequality research might begin with the question: Is there a relationship between student SES and creativity?

However, as will be subsequently demonstrated, even a quick glance at the creativity research shows this way of asking the question to be overly simplistic. In terms of educational outcomes, creativity is a particularly complex construct; it can be analyzed at different levels of analysis, each often consisting of many components. Examining some sort of overarching creativity variable and its association with SES is thus not likely to yield meaningful, actionable findings. For this research task to become tractable, it seems that creativity needs to be analyzed at a more granular level. As is explored in more detail in the following chapter, an educational cognitive neuroscience framework provides exactly the sort of precision and granularity necessary for this task by providing a way to analyze SES and cognition in more specific ways.

As shown below, when we look at SES and creativity through this type of framework, we see the suggestion of certain cognitive and neural links between SES and creativity. In particular, we will explore one promising cognitive link between SES and creative cognition: executive functioning. Like the construct of creativity, however, executive functioning is also complex and any analysis thereof can benefit from a similar view towards component parts. Thus, the task for the researcher is getting more complex: the examination of SES, combined with components of creativity *and* components of executive functioning. The explorable interactions are many, so, we will argue that these three constructs be analyzed together as a learner *profile* of specific cognitive skills across levels of SES. This proves to be a more fruitful approach than looking for broad SES differences, of equal magnitude and direction, across all executive and creative cognitive skills, allowing instead for a potential diversity of relationships.

To revise the previous research question, the present work aims to answer a more precise inquiry: Do students from different SES backgrounds have different profiles of creative cognitive skills and underlying executive skills? As our review will show, there has been little work thus far explicitly or conclusively examining this from a neurocognitive perspective. The work that has been conducted has some theoretical and methodological limitations which constrain the ability to arrive at a direct answer. However, finding answers may have important implications for education, specifically regarding attaining creative equity and creative talent development.

This research seeks to contribute to this gap in our understanding. Situated in an educational cognitive neuroscience framework, we investigated a particular piece of a much broader research agenda ultimately aiming to understand the complex interactions between SES and creativity in schools: the relationship between student SES and particular cognitive skills thought to underlie the creative cognitive process.

Literature Review and Theoretical Framework

In order to piece together the educational cognitive neuroscience framework that supported this research, I will review a few different strands of research, weaving them together to argue that socioeconomic status (SES), executive functioning, and creative cognition can be fruitfully examined simultaneously. First, I will briefly review research related to the construct, measurement, and historical educational findings of SES. Second, I will review the social cognitive neuroscience literature, in which neuroscientists and cognitive psychologists have included the sociological construct of SES as a variable by which to parse specific neurocognitive outcomes. As one of the foci of this field, executive and prefrontal functions will be highlighted. Third, I will then introduce the nascent findings regarding the cognitive and neural underpinnings of creativity. Like the social cognitive neuroscience research, executive and prefrontal functions play an important role, particularly in three creative cognitive skills: divergent thinking (DT), insight, and associative processing. Finally, because these bodies of research, considered altogether, suggest possible connections between SES, executive skills, and creative cognitive skills, I will explore the limited work that has directly addressed SES and creativity. These studies will be critically evaluated in order to demonstrate why more research needs to be conducted on this topic. Research questions and hypotheses conclude this chapter.

Before starting the review, it is worth reiterating that our investigation of relationships between SES and creative cognition was not about seeking the presence of any gaps or deficits, particularly for lower SES students. Instead, the entirety of this research effort was viewed through and motivated by a cognitive profile perspective. Such a perspective provides for the possibility that both lower and higher SES students might have their own sets, or profiles, of cognitive strengths. This *non-deficit* (Ladson-Billings, 2007; Persell, 1981; Valencia, 1997; Valencia, 2010) way of considering students' diverse cognitive profiles is arguably a more helpful perspective for an educator who must ultimately differentiate instruction, by capitalizing on diverse strengths, in order to meet students' various needs – without viewing students as inherently deficient. As will be justified further below, viewing student differences by socioeconomic environments as adaptive – rather than deficient – allows for a different kind of educational philosophy; from such an adaptive, neurobiological perspective (e.g., Ellis & Del Giudice, 2014), students are seen not as deficient relative to some norm, but rather a product of their particular environments. A student produced from a particular environment will therefore have a particular neurocognitive profile of strengths and weaknesses in various environments, such as home, school, or workplace. Put another way, this study is about an examination of the potentially different environmental and cognitive paths to positive creative cognitive outcomes.

Socioeconomic Status: Construct and Measurement

Broadly, SES entails levels of access to capital of various kinds, such as social, financial, and cultural, to name a few (Bradley & Corwyn, 2002; Coleman, 1988). It encompasses these resources available to people and is typically measured in childhood, from a sociological perspective, by some combination of household financial resources, guardian educational attainment, and guardian occupation (Cowan et al., 2012; Entwisle & Astone, 1994; Hauser, 1994).

To help guide the subsequent review of SES research, it may be helpful to categorize the many permutations of childhood SES measures into a few buckets for ease of classification. First, SES is often analyzed in terms of groups of individuals or individually. In the first instance, there might, for example, be a comparison between a high SES group of students and a lower SES group of students. When analyzed individually, SES is usually treated as a continuous variable, with each student analyzed according to their own observed SES.

Second, SES might be analyzed using a single indicator, multiple indicators, or a composite comprised of multiple indicators. The three most common indicators are guardian finances, education, and occupation. In education research, a participant's eligibility for the National School Lunch Program (NSLP) is often used as a proxy for SES, or at least for the financial component. However, there is reason to believe that NSLP participation does not adequately reflect socioeconomic status (Harwell & LeBeau, 2010; Hauser, 1994). The financial aspect is also often captured by a measure of income (e.g., highest guardian income or total household income), but is also less frequently assessed by measures of wealth or similar tools that look beyond only the income-related financial resources. Guardian education typically refers to years of education or specific degrees attained. Finally, guardian occupation is typically coded or transformed to reflect some sort of rating of its cultural standing (e.g., prestige). A common example of a tool used to provide a numerical ranking for a guardian's occupation is the Hollingshead Index (Hollingshead, 1975).

Socioeconomic Status and Education

The relationships between SES and education outcomes have been explored for decades in sociology (e.g., see Parsons, 1959; Sewell, Haller, & Portes, 1969), and have been explored since across a variety of disciplines. These educational outcomes – including, for example, standardized test achievement, dropout rates, and educational attainment – are key indicators of inequalities that can be addressed. For example, Berliner (2009), reviewed a wide array of evidence about the environmental conditions of poverty and low SES *outside* of schools which ultimately predict disparate achievement outcomes *within* schools. Bradley and Corwyn (2002), reviewed a wealth of developmental psychology findings regarding SES, including empirical evidence connecting SES to health, cognitive outcomes, academic achievement, academic attainment, social and emotional growth, as well as the various proposed moderators and mediators of these inequalities. An important point to take away from findings like these is that students from lower SES households typically face a plurality of risks that are cumulative in their impact (Evans & Kim, 2010).

Notwithstanding this lengthy discussion in education and sociological research about various inequalities, very real differences as a function of SES still exist. According to the 2013 National Assessment of Educational Progress (NAEP; http://www.nationsreportcard.gov/), of those eligible for free lunch (an admittedly rough proxy for SES, as was noted above; Cowan et al., 2003; Harwell & LeBeau, 2010) in fourth grade mathematics through the National School Lunch Program (NSLP), 28% scored below basic, 47% basic, 22% proficient, and 2% advanced. Contrast these scores with those not eligible: 7% below basic, 34% basic, 46% proficient, and 13% advanced. There are similar trends in fourth grade reading, as well as both subjects at grade eight, suggesting a relationship between socioeconomic standing (at least the financial component) and educational achievement nationwide.

These numbers also suggest the existence of *excellence gaps* in America: discrepancies between the percentages of students eligible and ineligible for the NSLP scoring at an advanced level (Plucker, Burroughs, & Song, 2010).

Specific Neurocognitive Associations with Socioeconomic Status

Contrasted with the analyses of relatively broad outcomes (e.g., math achievement) in the educational research base, there are some neuroscientists and cognitive psychologists over the past two decades who have explored SES inequalities at a more specific neurocognitive level. Indeed, a *social cognitive neuroscience* perspective has emerged in order to consider how important sociological constructs like SES (i.e., the social context) might be related to particular neurocognitive functions. For example, there is a group of researchers who have examined how SES and childhood poverty relate to a battery of specific neurocognitive functions (Farah et al., 2008; Farah et al. 2006; Fernald, Weber, Galasso, & Ratsifandrihamanana, 2011; Hackman & Farah, 2009; Hackman, Farah, & Meaney, 2010; Lipina & Posner, 2012; Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005; Noble, Tottenham, & Casey, 2005; Waber, Forbes, Almli, Blood, & The Brain Development Cooperative Group, 2012). Many of these researchers voice the promise of uncovering more specific associations between socioeconomic standing and neurocognitive functioning than have been found in past research, ultimately leading to better targeted interventions of the skills underlying broad educational outcomes.

Founded in the non-human animal literature and extending into human studies, these researchers have sought to examine which effects of various constitutive elements of SES and poverty (e.g., stress, environmental enrichment, etc.) generalize to humans. The main finding is that specific environmental conditions that vary with SES are each differentially associated with specific neurocognitive functions. More simply, SES does not affect all parts of the brain and mind equally, nor can all of the affected parts trace their causes back to one set of constitutive SES elements. Relatively large disparities – favoring higher SES students – in language functioning are found in nearly all studies that examine it (e.g., Noble, Wolmetz, Ochs, Farah, & McCandlinss, 2006); though, moderate to small differences have also been found in executive and prefrontal functioning (Blair et al., 2011; D'Angiulli, Herdman, Stapells, &

Hertzman, 2008; Hughes & Ensor, 2005; Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009; Lipina et al, 2013; Mezzacappa, 2004; Raver, Blair, Willoughby, & The Family Life Project Key Investigators, 2013; Stevens, Lauinger, & Neville, 2009), as well as memory, mathematical cognition (Pappas, Ginsburg, & Jiang, 2003), amygdala and emotional functioning (Gianaros et al., 2008), and visual and spatial skills (e.g., Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005). For other cognitive skills, no associations with SES were found: for example, visuospatial and memory skills (Noble, Norman, & Farah, 2005) or reward processing (Noble, McCandliss, & Farah, 2007).

Many mechanisms – which are themselves directly related to the various forms of capital mentioned in the review of SES above – are proposed in order to link child SES to specific neurocognitive outcomes, such as chronic stress, environmental enrichment or stimulation, and parental nurturance (e.g., Hackman, Farah, & Meaney, 2010). Differential exposure to such environmental conditions results in differential developmental outcomes on some – but not all – neurocognitive functions. For example, there is a great deal of evidence suggesting that the experience of chronic stress may be one of the more substantial ways by which lower SES influences executive and prefrontal functioning, memory, and learning (Blair, 2010; Carrion & Wong 2012; Evans, 2003; Evans, Kim, Ting, Tesher, & Shannis, 2007; Evans, Schamberg, & McEwen, 2009; Joels, Pu, Wiegert, Oitzl, & Krugers, 2006; Juster, McEwen, & Lupien, 2010; Kim & Yoon, 1998; Lupien, Maheu, Tu, Fiocco, & Schramek, 2007; McEwen, 2013; Packard, 2009).

Executive Functioning Concepts

Before the subsequent discussion focusing on executive functioning and its role in this social cognitive neuroscience literature, it is useful to briefly define how a few terms are being used here. By executive functioning, we are referring to a collection of cognitive skills thought to depend, in large part, on the prefrontal cortex, which help to plan and control goal-oriented behaviors. Three of these cognitive skills which are central to this research are working memory, inhibitory control, and shifting. Working memory refers to the capacity a person has to simultaneously hold and manipulate information in consciousness. Inhibitory control concerns the ability to willfully exert influence to inhibit a prepotent response. Finally, shifting refers to an ability to flexibly change focus between multiple, often competing, demands.

Socioeconomic Status and Executive Functioning

Of the skills and functions explored by the social cognitive neuroscientists, executive and prefrontal functioning is particularly interesting. First, as will be demonstrated in this section, it is reliably predicted by child SES; in general, higher SES is related to better executive skills. Second, it is also – though, to a lesser degree – cited as an important area of cognition underlying creative cognitive skills, a topic explored in the next section. So, executive and prefrontal functioning may be a neurocognitive bridge between these two research bases.

Third, and perhaps more importantly, executive functioning consists of several skills that have been linked with so-called "higher-order thinking" and academic success. For example, Raver and Blair (2016) reviewed three of the most common executive functioning skills – flexible attentional control, working memory, and inhibition – and their links to student success in the classroom. Importantly, they also shared evidence about the malleability of these skills through educational interventions. Little (2017) presented findings based on a nationally-representative sample of early-primary-aged students suggesting differences in both working memory and executive flexibility by SES (he notes the importance of inhibition as well to studying executive functioning, but it was not available in the dataset to be analyzed). Lechuga, Pelegrina, Pelaez, Martin-Puga, and Justicia (2016) also provided evidence that working memory is important to verbal, quantitative, and classroom achievement with a sample of fourth-graders, and Lawson and Farah (2017) found that a statistically significant relationship between child SES and math achievement was partially mediated by executive functioning measures of memory span, working memory, and shifting. In sum, not only is there evidence that shifting, working memory, and inhibition are important for academic success, there is also evidence that these skills are distributed inequitably across SES, a point now elaborated upon.

Executive and prefrontal advantages for higher SES children. Farah and colleagues (2006) examined neurocognitive functioning in relation to SES with a broad battery of measures, given to a sample of 60 children, ranging in age from 10 to 13. They analyzed SES by low and middle groups, distinguished by receipt of welfare assistance, Hollingshead occupational ratings, and postsecondary educational attainment. The executive measures captured three cognitive functions: working memory, cognitive control, and reward processing. They found significant SES differences in working memory and cognitive control favoring the middle SES children, but no differences in reward processing.

Noble, McCandliss, and Farah (2007) similarly employed a wide battery of neurocognitive measures, but their study differed in its continuous operationalization of SES, indicated by education, income, and occupation. The sample was comprised of 150 first-graders. Similar to Farah et al. (2006), they measured working memory, cognitive control, and reward processing, finding again that SES significantly predicted differences in working memory and cognitive control, but not reward processing.

Noble, Norman, and Farah (2005) followed a similar protocol of employing a wide battery of tasks, but with 60 kindergarten students. They measured SES similar to Farah and colleagues (2006), using a group-based analysis distinguished by education, Hollingshead rating, and an income-to-needs ratio. Their results showed that SES was positively predictive of executive skills overall (as a composite), but only predictive of inhibitory control – and not the spatial working memory – when analyzed separately.

Hughes and Ensor (2005) investigated executive functioning and theory of mind in early childhood (*n* = 140 two-year-old children). To recruit children from low SES family backgrounds, they focused on households that met multiple indicators of educational, occupational, and income disadvantage. Five different tasks were used to assess executive functioning, which variously captured skills like working memory, cognitive control, and flexible rule-following. Among other results, they found that social disadvantage was predictive of executive functioning.

Lipina and colleagues (2013) researched executive functioning and fluid intelligence, the latter of which may be associated with executive and prefrontal functioning (Blair, 2006). This research was conducted in Argentina with a sample of 250 students with a mean age of 4.87 (*SD* = 0.59). Their SES measure was designed to indicate unsatisfied basic needs and other experiences of disadvantage in childhood related to the common indicators of education, occupation, and income, and their cognitive battery was meant to assess non-verbal executive control. They found that the children classified as having unsatisfied basic needs performed significantly lower on most – though not all – of the tasks, including those assessing cognitive control, working memory, different attention networks, and fluid intelligence. As an example of similar performance across groups, children with both satisfied and unsatisfied basic needs performed similarly in reaction time on the different subtasks of the Attentional Networks Test.

Mezzacappa (2004) examined the relationship between a continuous composite measure of SES and a battery of attentional processes measures (i.e., the Attention Network Test) connected with executive and prefrontal functioning. In this sample of children (n = 249) ranging in age from about four to seven, Mezzacappa found that alerting, orienting, and executive attention processes were quicker and more accurate in higher SES children; the higher SES children responded more proficiently to the alerting attention cues and interference demands of the executive attention cues.

Fernald, Weber, Galasso, and Ratsifandrihamanana (2011) investigated working memory, fluid reasoning, sustained attention, and inhibitory control – among a broader battery of neurocognitive measures – in relation to SES, measured by indicators of education and finances. Their nationally representative sample of children ranging in age from 3 to 6 years in Madagascar was somewhat unique compared to the above samples due to relatively greater overall levels of depravation and poverty. However, even among this particularly disadvantaged sample, SES had a positive relationship with cognitive outcomes, including memory, working memory, sustained attention, visual-spatial processing, and fluid reasoning. Overall, they found that these cognitive differences by SES were nearly double at age six compared to what they were at age three.

In addition to the above *cognitive* findings on measures thought to be largely localized in the prefrontal cortex, some researchers present direct evidence relating SES to electrical recordings of prefrontal *neural* activity. For example, one group analyzed event-related potential (ERP) measures of prefrontal electrophysiological activity, in addition to cognitive measures, in a sample of 28 children ranging in age from 7 to 12 (Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009). They used three indicators of SES – education, income, and an income-to-needs ratio – to distinguish higher and lower SES groups. The cognitive assessments of executive functioning included measures of working memory, visuomotor attention, cognitive flexibility, inhibitory control, and semantic fluency. ERP results were recorded during an attention task with standard, target, and novel stimuli. For the cognitive tasks, the results showed an advantage for higher SES children with working memory, cognitive flexibility, and semantic fluency, but not visuomotor attention or inhibitory control. Shifting to the ERP results, they found significant differences between the groups in the prefrontal cortex components related to visual attention and attention to novel stimuli.

Two groups of researchers have examined ERP measures of selective auditory attention, a component of executive and prefrontal functioning (D'Angiulli, Herdman, Stapells, & Hertzman, 2008; Stevens, Lauinger, & Neville, 2009). D'Angiulli, Herdman, Stapells, and Hertzman (2008) created a composite measure of SES based on education and occupation, as well as neighborhood quality and single parenthood status. Twenty-eight students – recruited from middle-school grades, with an approximate mean age of 13 – engaged in a task in which they were asked to pay attention to two pure auditory tones while ignoring two others, indicating their attention to tones of a particular frequency and duration by pressing a button. They found that, though the students from both SES groups performed similarly behaviorally, the students from the low SES group displayed ERP results suggesting that they pay similar attention to relevant and irrelevant auditory stimuli, whereas such brain activity for irrelevant stimuli was diminished in the higher SES group. Stevens, Lauinger, and Neville (2009) recruited a sample (n = 32) that was younger than that of D'Angiulli and colleagues (M = 6.1, [3-8]). Instead of auditory tones as the stimuli, Stevens and colleagues used narrative recordings, one being a distractor and one being that to which children were instructed to attend. Again, they found evidence of reduced selective attention in the lower SES group (distinguished by indicators of education and occupation), with this group being less able to filter out the distracting, irrelevant stimuli.

Executive skills with no socioeconomic differences or with possible advantages for children of lower SES. Importantly, however, not all SES-executive and prefrontal functioning findings reveal lower performance amongst lower SES children. On some functions no differences are found. On others lower SES participants demonstrated higher performance than their more affluent peers. For example, Farah and colleagues (2006) found that children were statistically similar on reward processing, and Noble, McCandliss, and Farah (2007) found no SES differences in reward processing, nor on specific working memory and cognitive control tasks.

Perhaps even more interesting, some scholars – particularly those who have adopted an evolutionary life history approach (e.g., Ellis & Del Giudice, 2014) – have uncovered cognitive functions on which lower SES participants demonstrated an advantage relative to their higher SES peers. In one recent example, Mittal, Griskevicius, Simpson, Sung, and Young (2015) put forth the concept of early life conditions resulting in adaptive – as opposed to deficient – behaviors. Within this framework, they proposed that children with different early environments (measured by a retrospective participant assessment of unpredictability in early childhood and a measure of childhood SES) might have differentially adapted cognitive functions such that adults from both low and high SES backgrounds might each have relative, but different, cognitive strengths. Specifically, they looked at two measures of executive functioning: inhibition and shifting. They found that adults who had grown up in unpredictable environments performed better than those who did not on the shifting task, but not on the inhibition task when the context of the executive functioning assessments was experimentally manipulated to be uncertain. Furthermore, they only observed this finding with their measures of childhood uncertainty, not SES. However, the experience of uncertainty is a common feature of a lower SES environment (Bradley & Corwyn, 2002), and even the prospect of observing such a cognitive relationship with childhood SES deserves more attention, particularly *during* childhood, as opposed to retrospectively.

With these executive and prefrontal findings from the social cognitive neuroscience literature as a foundation, it is worth pursuing how the specific neurocognitive skills implicated (i.e., working memory, inhibitory control, and shifting) might underly a higher-order skill like creativity. Waber, Forbes, Almli, Blood, and The Brain Development Cooperative Group (2012) made the argument that SES effects tend to be greater when looking at integrative cognitive functions (i.e., higher-order functions, recruiting multiple neurocognitive systems) versus lower-level functions (e.g., a specific sub-function, such as working memory, within a neurocognitive system, such as executive functioning). As shown next, there is some evidence that executive and prefrontal functioning may contribute to creative behavior, and since relationships have been found between SES and executive skills, the above line of reasoning from Waber and colleagues suggests that SES might be even more predictive of creativity – particularly insofar as it is an executive-based skill.

The Executive and Prefrontal Underpinnings of Creative Cognition

Modern creativity research began in earnest around the middle of the twentieth century (Runco & Albert, 2010). Since then, there has been a proliferation of theories, paradigms, and perspectives regarding how best to empirically examine the construct of creativity (Kozbelt, Beghetto, & Runco, 2010). Arguably, all of these theories in some way address portions of a common definition of creativity offered by Plucker, Beghetto, and Dow (2004): "Creativity is the interaction among *aptitude, process, and environment* by which an individual or group produces a *perceptible product* that is both *novel and useful* as defined within a *social context*" (p. 90). A definition like this demonstrates why proposing any simple measure of a broad, complex behavior like being creative is likely an impossible – or meaningless – task. Among the various frameworks for examining different aspects of this definition of creativity are those that view creativity through cognitive or neuroscientific lenses (e.g., Dietrich, 2004; Finke, Ward, & Smith, 1992). These neurocognitive frameworks focus primarily on the aptitude, process, individual, novelty, and usefulness aspects of the definition.

One of the early and oft-cited examples of what might be loosely termed a cognitive description of the creative process is given by Wallas (1926). In *The Art of Thought*, Wallas explores many perennial issues in psychological and brain sciences, though, by far the most frequently cited contribution in modern creativity literature is his passage describing the stages of creative thinking: preparation, incubation, illumination, and verification (p. 38). As he conceives them, preparation is the stage at which we initially approach a problem; incubation is a largely unconscious, or implicit, process during which associations are made in memory; illumination might be thought of simply as the moment of insight, when a creative solution enters consciousness; and, verification is the stage when that solution is consciously, systematically, and rationally evaluated.

There are, of course, much more modern accounts of creativity inspired by cognitive psychology and neuroscience (e.g., Kaufman, Kornilov, Bristol, Tan, & Grigorenko, 2010). The foci of these accounts are on specific cognitive capacities and neural circuits thought to contribute to creative behavior. Perhaps the most prominent voices regarding the cognitive underpinnings of creativity belong to Thomas Ward and his colleagues (Finke, Ward, & Smith, 1992; Smith, Ward, & Finke, 1995; Ward & Kolomyts, 2010). They introduced the *creative cognition* approach as one of the foundational viewpoints for viewing creativity through a cognitive lens. Like the other cognitive and neuroscientific accounts of creativity proposed below, the essence of the creative cognitive approach consists of a combination of knowledge and the ways in which that knowledge is manipulated (e.g., accessed, combined, evaluated for novelty, etc.). The basic theory behind this approach is known as the *Geneplore Model*, which seeks to explain the association and manipulation of ideas by several cognitive processes that may or may not produce a creative idea (Ward & Kolomyts, 2010). At its core, this approach is about getting to as granular and specific a level as possible in describing the cognitive processes that ultimately combine to produce creative output. To Ward and colleagues, such processes include – but are not limited to – retrieving memories, combining ideas, analogizing, and various stages of problem discovery and solving.

An even more recent neurocognitive account of creativity is offered by Dietrich (2004), based upon the idea that accounts of creativity must inevitably be grounded in neurocognitive findings. He developed a heuristic of four different types of creativity, each of which is a cross between two dimensions: the type of processing and the type of information being processed. The two types of processing that he distinguished are deliberate (i.e., analytical and attention-directed thinking, initiated by the prefrontal cortex) and spontaneous (i.e., unconscious thinking that eventually enters working memory in the prefrontal cortex, for example, in the form of an insight), whereas the two types of information are cognitive and emotional. These types of creativity might be usefully thought of as different profiles of creativity, which, when the state of the science progresses far enough, might provide pathways to individualize creativity in the classroom. Dietrich's emphasis is on functional neurological circuits to distinguish these four types of creativity, with the prefrontal cortex playing a key role. He proposes that emotional information is largely contributed by the limbic system, whereas cognitive information – closely related with long-term memory – is related to the temporal, occipital, and parietal lobes. Playing an integrative role, with its various executive functions, the prefrontal cortex is proposed to be the key area of the brain where novel ideas are brought into consciousness and evaluated for their creative contribution, thus implicating executive functions such as working memory (e.g., the ability to consciously process potentially creative associations), shifting, cognitive control, and the ability to evaluate novel ideas for their utility. There is a distinction between knowledge on the one hand, conceptualized as providing the content and potential associations in creative processes, and creative thinking on the other, largely about the prefrontal cortex integrating and evaluating the knowledge in order to result in a novel and useful idea or expression.

Dietrich (2004) grounds his theoretical framework in empirical findings regarding neurological processes that are part of ordinary mental processes; that is, he proposes that creative cognition is similar to other mental processes studied by cognitive neuroscientists in that they share many of the same neural circuits, albeit with different outcomes. This view is similar to Ward and Kolomyts (2010), as well as to Kaufman, Kornilov, Bristol, Tan, and Grigorenko (2010), who also suggest that a cognitive phenomenon like creativity must have a neural basis that can, ideally, be discovered not unlike other common cognitive processes. Dietrich also hypothesized that, because the prefrontal cortex is critical to creative cognition, *and* because this particular part of the brain has a protracted developmental trajectory, creativity might look different in children than it does in adults – a prediction that should be especially true for those types of creativity that are heavily dependent upon the prefrontal cortex (e.g., deliberate processing). In order to begin to empirically examine this theoretical framework, he concluded his explication with an explicit recommendation to incorporate cognitive measures for which the neurological underpinnings are well established and localized in new cognitive examinations of creativity.

Following in a similar vein a few years later, Dietrich and Kanso (2010) reviewed 63 neuroscientific studies that have explored creativity in terms of divergent thinking, artistic and musical talent, or insight. Based upon many contradictory, varied, or null findings in this still nascent literature, they concluded – like Dietrich (2004) – that, from a neurocognitive standpoint, there must be multiple types of creativity and note that creativity, broadly, recruits numerous circuits and areas of the brain. Put more concisely, from a neurocognitive standpoint, creativity is best conceived of as pluralistic; a broad notion of creativity is problematic. However, they do emphasize that the prefrontal cortex is frequently implicated in these findings, particularly in divergent thinking and insight studies; though, there is no consistency regarding particular areas and functions within the prefrontal cortex, and there may be a distinction between different types of creativity depending upon whether or not areas of the prefrontal cortex are relatively activated or deactivated. A similar point is made by Kleibeuker, De Dreu, and Crone (2016) when they described the developmental trajectories of creativity in adolescence and adulthood. They emphasize both the multiple, distinct cognitive skills underlying creative development and also the reliance on prefrontal and executive processes.

Dietrich and Kanso (2010) draw specific attention to divergent thinking measures, concluding that they may not be the most promising method for exploring specific neural circuits contributing to creativity given the likely plurality of cognitive and neural functions recruited – an argument similarly applied in critique of Wallas' (1926) stages of creative thought as rather coarse composites of many more granular neurocognitive processes. Still, divergent thinking tasks are arguably very diverse in task demands and content (as, indeed, they recognized in their review of prior research), and perhaps a better understanding of the cognitive underpinnings of different *types* of divergent thinking tasks is needed before these can be usefully employed in neurological studies. They suggest that future research needs to begin to consider different types of creativity and the many possible neurocognitive sub-processes that might differentially underpin them, an approach which they argue might begin to allow for inroads for many of the larger theoretical controversies in the field (e.g., the degree to which creativity is domain-specific or how creativity might manifest across different age ranges), a sentiment similarly echoed by Kaufman and colleagues (2010). However, with the present state of neurocognitive knowledge of creativity, more empirical work on the foundations of creative cognition needs to be performed in order to arrive at a theoretical framework which might address such issues.

Beyond Ward, Dietrich, and their colleagues, other creativity researchers have also implicated executive and prefrontal functioning. In a review of the evolutionary biological research concerning human creativity, Gabora and Kaufman (2010) emphasized the importance of the development of the prefrontal cortex in the evolutionary history of human creativity: as overall brain size enlarged, allowing for more encoding and possible associations in the brain, they hypothesize that higher order functions supported by the prefrontal cortex were important for adaptively utilizing these complex neural networks for creative ends. They also pointed to the evolved ability to shift seamlessly between divergent and convergent thinking as crucial to the cognitive processes producing creative ideas and products. Benedek and Neubauer (2013) made a similar argument in their empirical investigation of Mednick's (1962) associative processing model of creative cognition. Specifically, they found that it is not individual differences in the associative organization of memory which are primarily responsible for creativity, but rather what they hypothesize as being the differences in individual ability to adaptively utilize executive functions to process the contents of associative memory in service of creative output. Finally, in their article aimed at connecting creativity research with the classroom, Gregory, Hardiman, Yarmolinskaya, Rinne, and Limb (2013) point to research emphasizing executive functioning as a crucial foundation for creative cognition.

Several neurological studies converge on similar conclusions. In a functional magnetic resonance imaging (fMRI) study of the neural underpinning of creative jazz improvisation, Limb and Braun (2008) found that improvisation was associated with dissociated neural activity in the prefrontal cortex, with deactivation in some areas and increased activation in others; however (as was suggested by work cited above) they also found widespread activation in other areas of the brain, pointing to the complexity of creative activity. Jung and Ryman (2013) reviewed structural and functional brain imaging evidence regarding creativity through the lens of Wallas' (1926) stages. Like, Limb and Braun, they found evidence of dissociative activation in the prefrontal cortex; these dissociative findings in the prefrontal cortex may point to a common conceptual theme in the literature of the importance of both disinhibition and inhibition during the creative process, perhaps for different types of creativity (e.g., as per Dietrich, 2004). Rutter and colleagues (2012) examined what they termed *conceptual expansion* (a state of mind indicated by a person's judgment that a stimulus is both novel and appropriate – both key criteria for creativity) using fMRI. They found that when participants viewed novel *and* appropriate stimuli – as opposed to those that were only novel or only appropriate – a unique neural circuit throughout frontal and temporal areas of the brain was activated.

In all of this neurocognitive work exploring the underpinnings of creativity, and particularly those articles addressing executive and prefrontal functioning, three creative cognitive skills are given the most attention: divergent thinking (DT), insight, and associative processing. Below, each of these three skills are reviewed, in turn, regarding conceptual definitions, measurement, and connections with executive and prefrontal functioning. Of note at this point, Fishkin and Johnson (1998) make the argument that measuring creativity in children can be quite different than measuring creativity in adults since it may not be as easy to recognize creative *behaviors* or *potential* for creative accomplishments. Perhaps such cognitive constructs provide an ideal measurement strategy for examining the precursors of creative behaviors in children.

Divergent thinking. Whereas convergent thinking emphasizes arriving at a single, correct solution, DT involves generating many different ideas. Runco (2010) suggests that measures of DT can offer relatively objective indicators of creative potential, creative problem solving, or the natural generation of ideas that occurs in everyday life. However, DT is not synonymous with creativity and these measures are not simple measures of creativity. Instead, such measures are better classified within a larger set of measures in the psychometric literature which get at ideation, or the generation of ideas (Runco, 2010). Plucker and Makel (2010), as well as Runco (2010) trace the earliest empirical models of creativity including DT to Guilford in the 1950s and then Torrance in the 1970s. Indeed, the Torrance Tests of Creative Thinking are probably the most widely employed measures of DT thinking today. Many researchers have commented on the prominence of DT measurement in the field of creativity research (Fishkin & Johnson, 1998; Kaufman, Plucker, & Russell, 2012; Plucker & Makel, 2010; Runco, 2010), suggesting simultaneously that these measures are often too heavily relied upon to indicate all of creativity, but also that they are indeed an important part of creative thought.

Prior empirical work has also uncovered many important characteristics of DT and its measures. Kim (2008) found that DT tasks are generally more highly correlated with creative achievement than IQ scores. While most studies seem to examine DT in later childhood and beyond, there is some evidence that this skill can be meaningfully measured as early as age two (Bijvoet-van den Berg & Hoicka, 2014). This ability to measure DT throughout most of the lifespan may be important based upon a review of evidence by Runco (2010) suggesting that DT can be intervened upon, developed, and improved.

As Plucker and Makel (2010) review, measures of DT generally require a person to generate as many different ideas to a prompt as possible and come in either verbal or figural forms. There are many variations on this basic idea of measuring divergent thinking: for example, whether or not the test is timed, measuring different types of divergent thinking, and so on. The results of these assessments are commonly scored for fluency (i.e., the number of responses generated), originality, flexibility (i.e., the number of categories of ideas), and elaboration. However, there are numerous viewpoints regarding how best to score divergent thinking results (e.g., Kaufman, Plucker, & Russell, 2012; Plucker, Qian, & Wang, 2011; Silvia, 2011; Silvia, Martin, & Nusbaum, 2009).

Of the three creative cognitive skills here examined, there is perhaps the most evidence thus far connecting this one to executive and prefrontal processes. For example, Mayseless, Eran, and Shamay-Tsoory (2015) examined the originality aspect of DT tasks using fMRI. Based upon prior research suggesting the importance of generating associations and inhibiting immediate or obvious responses for original ideation, they hypothesized that prefrontal brain areas related to associative processing and cognitive control would be functionally important for generating original ideas. Indeed, they found that several areas of the brain were activated during original idea generation, including areas in the prefrontal cortex, *and* that greater originality was associated with higher levels of activation in some of these areas. They noted that these areas include some that are commonly associated with the ability to make flexible associations, as well as cognitive control. Their conclusion was that DT necessitates neural systems responsible for generating and evaluating original ideas.

Using multilevel modeling in an educational context, Kuhn and Holling (2009) explored relationships between DT and several other variables, including cognitive variables addressing processing capacity (which they roughly equate with fluid intelligence), processing speed, and memory. In their sample of 1098 students, clustered within 55 different classrooms, they found that processing capacity and processing speed – but not memory – were significantly correlated with DT. As noted elsewhere, some researchers have associated fluid intelligence with executive or prefrontal functioning (e.g., Blair, 2006).

Gilhooly, Fioratou, Anthony, and Wynn (2007) conducted two experiments to better understand strategies used and the underlying executive functions involved in performance on alternative uses DT tasks. In terms of strategy use, in the first experiment they found that originality scores were correlated with the use of particular strategies; this sort of planning and strategizing is typically associated with executive or prefrontal processes. In the second experiment, participants were asked after completing the task to indicate which responses were perceived as being new to them and which were perceived as being old. Results of regression analyses suggested that letter fluency was positively related to fluency of new responses and category fluency was positively related to fluency of old responses. They interpreted these results by first suggesting that letter fluency more heavily loads on executive processes than category fluency and then suggesting that fluency of new ideas on DT tasks is thus more heavily correlated with executive processes.

Nusbaum and Silvia (2011) employed latent variable analysis in order to take a different analytical approach to the long-standing debate in creativity research about the relationship between creativity and intelligence. Their paper reports the results of two studies with DT scores for unusual uses tasks. In the first study (n = 226), they found that fluid intelligence was moderately related to DT performance, and also that this relationship was mediated by executive shifting (measured here as the number of different categories generated on the DT task). In the second study (n = 188), the researchers gave some of the participants a strategy to help them with the DT task. Fluid intelligence was again measured, and they found that, for participants with higher fluid intelligence scores, having access to the strategy improved DT, but having the strategy did not make a difference for those lower in fluid intelligence. They ultimately concluded that fluid intelligence, executive switching, and strategy use are all central to DT performance, implying that the prevailing view that creativity and intelligence are relatively distinct constructs be revised. To them, DT is an executive-heavy process.

Insight. A subset of convergent thinking, insight is clearly related to the stages of incubation and illumination in Wallas (1926), and it is commonly recognized as the "ah-ha" moment when a creative idea is generated – though, it may also incorporate divergent and associative processes, either consciously or unconsciously, to arrive at that moment. Dietrich (2004) explicitly recognized this part of creative cognition in his neurocognitive framework as spontaneous processing, also related to discussions of implicit or unconscious thinking, and Dietrich and Kanso (2010) recognized that this convergent process is crucial to understanding the neurocognitive foundations of creativity. Lee and Therriault (2013) considered this a convergent thinking dimension of creativity, while also noting that this aspect of creative cognition receives far less research attention than DT. Some of the tasks which have been used to assess this part of creative cognition include the Remote Associates Test (RAT), as well as different insight problems (sometimes commonly referred to as riddles or "brain teasers"; Lee & Therriault, 2013). Common to these various tasks is the requirement for participants to go beyond the immediately obvious in order to ultimately generate a novel, less obvious – yet appropriate – solution. (i.e., to overcome initial ambiguity in problem solving). Solutions are not arrived at by explicit, analytical, or strategic paths.

Lv (2015) examined insight problem solving and suggested that different executive functions influence different portions of the insight problem solving process. Two experiments were conducted, each with about 100 participants; the first explored verbal insight problem solving and the second spatial insight problem solving. A think-aloud protocol was employed so that the researcher could use verbal cues from participants to later analyze different stages of the problem solving process. The two stages identified in this study were the initial searching stage followed by a restructuring stage. (That the insight problem solving process might be meaningfully separated into stages could give support for a stage view of creative thought like Wallas' [1926], as well as for the creative cognition viewpoint [Finke, Ward, & Smith, 1992] that broader creative processes can be examined in terms of their sub-processes.) In addition to solving the insight problems, participants were also asked to perform a series of working memory span and inhibition tasks. Lv found that working memory was mainly associated with the initial searching phase while inhibition was primarily associated with the restructuring phase.

It is worth making a distinction here between cognitive control and inhibitory control, because, particularly in the context of creative cognition, they are not the same. Simply, inhibitory control is a specific, narrower instance of cognitive control. Whereas inhibitory control generally suggests control with inhibiting a particular cognitive response, cognitive control has a broader connotation for a person's ability to executively control many different cognitive processes. For example, cognitive control could also mean controlling *dis*inhibition; that is, cognitive control is not necessarily just the opposite of disinhibition, as inhibition is. This is particularly crucial in the field of creativity because some have implicated flow-like, unconscious, or deregulated attention states as important for some creative processes (e.g. Csikszentmihalyi, 1990; Limb & Braun, 2008). Indeed, McPherson and Limb (2013) noted the importance of *controlling* flow-like, disinhibited states for expert jazz improvisational musicians. Therefore, cognitive control can mean both inhibiting usual responses in a divergent thinking task in order to generate more creative ideas, but also controlling disinhibition in order to engage flow-like states and unconscious processes in an insight task.

Though Lv (2015) reported finding a connection between working memory and insight problem solving, the issue is far from settled in the research base. In a series of experiments (DeCaro, Van Stockum Jr., & Wieth, 2016) and back-and-forth commentaries (Chuderski & Jastrzebski, 2017; DeCaro, Van Stockum Jr., & Wieth, 2017), two research groups presented inconsistent claims about whether higher working memory capacity or lower working memory capacity aids insight problem solving, as well as whether or not the level of working memory capacity considered beneficial might depend on aspects and stages of the problem-solving process.

One other example implicating executive and prefrontal functioning in insight comes from a pair of experiments conducted by Cerruti and Schlaug (2008). Based on previous findings demonstrating that transcranial direct current stimulation on specific parts of the brain had behavioral performance effects on tasks that substantially drew from that stimulated portion, they hypothesized that stimulation of a certain region of the prefrontal cortex implicated in verbal task performance might improve performance on the RAT. Support for this hypothesis came from evidence that the RAT is both a complex verbal task and also substantially reliant on executive abilities. Their hypothesis was supported: anodal stimulation within the prefrontal cortex improved RAT performance. However, even given the intriguing findings from this collection of studies, more work is clearly needed to clarify the nuances of how insight is related to particular executive functions.

Associative processing. Mednick's (1962) foundational work suggests associative processing as another important creative cognitive skill. This skill is characterized by the particular chain of ideas that is generated by a person; or, how fluent one is in retrieving ideas from their associative memory network. Wallas (1926) recognized the importance of these associative processes in the preparation and incubation stages, where ideas associated with a problem are initially explored explicitly and then unconsciously, respectively. Dietrich (2004) included the associative memory networks of the brain as a key part of his neurocognitive framework. There is some empirical evidence supporting the importance of associative processing for performance on measures of creativity (e.g., Lee & Therriault, 2013); however, others have suggested the role of associative processing in creative behavior to be modest at best, instead emphasizing executive processes that help a person *navigate* their associative networks in ways conducive to creative behavior (e.g., Benedek & Neubauer, 2013). This skill is often assessed by providing a person with an anchor prompt (e.g., a letter of the alphabet) and asking them to generate as many related ideas, or associations, as possible, with higher fluency scores (i.e., appropriate responses generated) indicating greater skill. Measures like the RAT may also tax this skill insofar as it – and others – require successfully navigating a chain of associations in order to arrive at a solution.

While addressing the broader issue of domain-specificity versus -generality in creative performance on divergent thinking tests, Diakidoy and Spanoudis (2002) present findings which are relevant to the importance of associative processing. Specifically, by comparing student performance on content-general and content-specific divergent thinking measures, across various types of divergent thinking tasks, they concluded that there are likely general cognitive processes underlying all divergent thinking performance, as well as content- and task-specific factors. For example, they suggested that the knowledge associations activated on a particular task may play a role in mediating divergent thinking performance. That is, the associative knowledge structure may interact with general divergent thinking skills in producing creative performance. Dai and colleagues (2012) also reported some evidence of task-specificity across their different DT tasks.

Mentioned briefly above, Benedek and Neubauer (2013)'s study sheds light on the relative importance of memory and executive functions in associative processing. The aim of their study was to empirically test specific hypotheses derived from Mednick's (1962) associative account of creative cognition. A continuous free word association task was used in order to examine whether the chain of associations generated by more creative participants (as measured by divergent thinking performance and self-reports) was "flatter": that is, the ideas generated in association with an anchor prompt were relatively equal in their strength of association to the prompt. They reasoned that these flatter associative hierarchies should result in more creative people generating a steady stream of responses throughout the task since the ideas are associated to the prompt with roughly the same strength (and thus might be accessed similarly). This in contrast with less creative individuals who were hypothesized to trail off after initial, dominant ideas are generated because subsequent ideas associated with the prompt are less strongly associated. It was also hypothesized that, overall, more creative people should generate more novel responses because their associations tend to be of similar dominance throughout the hierarchies, facilitating access to ideas based off a prompt that are less easy to access (due to weaker strength of association) for less creative individuals. Ultimately, they found that the shapes of the associative hierarchies, in terms of the associative strengths of successive responses, was not as important in distinguishing the creative from the less creative. Rather, it was the ability of the creative individuals to *process* the associative hierarchies which was more important; the more creative individuals were able to more fluently move through associative chains and thus also generate rarer responses. Discussing their results, they hypothesized that executive processes such as inhibitory control may play an important role in associative processing – and ultimately creative thinking – because this skill may help with inhibiting common or already provided responses so that new and perhaps more novel responses can be generated. In this sense, inhibitory control allows a person to break from a sequence of perseveration, a crucial skill for creative behavior. This is similar to what was suggested by Dietrich (2004): executive and prefrontal functioning are crucial for processing associative memories and ultimately yielding creative cognition.

Simultaneously considering divergent thinking, insight problem solving, and associative processing to explore creative cognition. Lee and Therriault (2013) provide an example of how all three skills discussed here (i.e., divergent thinking, insight problem solving, and associative processing) might be simultaneously considered. They conducted a latent variable analysis in order to explore the roles of various cognitive underpinnings of the creative process. Specifically, they examined the roles that working memory and intelligence played in associative fluency, divergent thinking, and insight. Their rationale for choosing to examine these three creative constructs as cognitive underpinnings of creative thought was founded in their literature review suggesting that these three are among the most well-established (as we similarly argue here). They specifically mentioned that it is problematic to reduce a complex process like creative cognition to just divergent thinking, as is often done in creativity research. Multiple indicators of creative cognition are needed, not the least because they end up providing empirical evidence in their study that insight and divergent thinking are rather statistically distinct parts of the creative process. In their sample of 265 participants, Lee and Therriault (2013) found evidence which they concluded suggests a distinct pattern amongst the various cognitive constructs: first, associative fluency contributes to both divergent thinking and insight performance; and, second, both working memory and intelligence explain variance in the creative cognitive abilities, though primarily through associative fluency. Thus, working memory is an important cognitive foundation – though perhaps in different ways – for three creative cognitive skills. They ended by explicitly calling for more research exploring the relationships among granular cognitive processes underlying creative cognition.

There are opportunities to improve upon and expand the work of Lee and Therriault (2013). For example, the theoretical and empirical background they provided in their article suggests that, not only working memory, but also other executive functions (e.g., inhibitory control and executive shifting) might play a role in the different creative processes. It should be equally important to understand the relationships of these other executive functions to different creative cognitive skills. Also, they used what is termed a *snapshot* scoring method for one of the divergent thinking tasks, a method which has been evaluated by Silvia, Martin, and Nusbaum (2009). Silvia and colleagues suggested that this method may not be the optimal choice when divergent thinking is a crucial, focal construct being studied, particularly because the more time-intensive scoring methods (discussed elsewhere) may be more reliable. Finally, though they provide a strong rationale for conducting a latent variable analysis, it is not always clear that the goodness of fit statistics were properly interpreted. For example, it has been suggested that acceptable root-mean-square error of approximation (RMSEA), confirmatory fit index (CFI), Tucker-Lewis index (TLI), and standardized root-mean square residual (SRMR) values of between .05 and .08, above 0.90, above 0.90, and less than 0.05, respectively, suggest adequate model fit (Schumacker & Lomax, 2016). Fit indices for their final, accepted model (RMSEA = 0.06, CFI = 0.82, TLI = 0.79, and SRMR = 0.06; p. 313) do not necessarily suggest adequate fit. Given these issues, some of the relationships amongst the cognitive constructs which they found need to be replicated. Regardless, given the complexity of the cognitive process of creativity demonstrated in the work cited above, it is evident that multiple parts of that process should be studied simultaneously.

The state of the research regarding executive functioning and creative cognition. Considering all of these creative neurocognitive findings as a whole, it is important to simultaneously appreciate the impressive empirical advances that have increased our understanding of creative cognition, while also tempering this appreciation with an honest assessment of what can actually be said at this point in the development of the field. The above studies provide some evidence that creativity is reliant upon executive and prefrontal functions. Some executive functions have been offered in particular, such as working memory, inhibitory control, and shifting. Though, these suggestions are just as often based in untested hypotheses and theories as they are in empirical findings. The evidence implicating prefrontal neural functioning is more ambiguous; though the prefrontal cortex is consistently noted as being important in neuroscientific studies, the mechanisms are not at all clear at this point. Indeed, some researchers have pointed out that the evidence to date concerning the neural underpinnings of creativity remains largely ambiguous (Dietrich & Kanso, 2010; Haier & Jung, 2008; Jung & Ryman, 2013; Kaufman et al., 2010).

Perhaps because of this largely unexplored research terrain, Silvia (2011) has called for more work that does not simply use measures indicating creativity – like divergent thinking assessments – as outcomes, but also as means for revealing more specific cognitive processes that might underlie creative cognition. In particular, and as an example, he hypothesized that certain executive functions might be differentially important for different types of divergent thinking tasks, but more work is needed in order to begin to establish such cognitive underpinnings.

McPherson and Limb (2013) tried to offer a partial explanation for why this ambiguity characterizes the current state of research by briefly exploring some of the inherent difficulties in trying to study creativity from a neuroscientific perspective, with the scientific method. For example, they noted that the novelty associated with creativity makes it difficult to capture and examine systematically. They also presented a sort of paradoxical idea: because creativity is such a complex phenomenon, it might be difficult to examine in smaller parts without then missing the synergy that might result in creative thought; conversely, without looking at such smaller pieces of creativity, it may be too unwieldy a construct to examine at all. It may simply be that creative cognition is not as neatly localizable as other neurocognitive functions, as Dietrich and colleagues have suggested (Dietrich, 2004; Dietrich & Kanso, 2010). However, McPherson and Limb are quick to counter that it is imperative that valid scientific means are used to study creativity given its central importance to human existence and societal progress.

So, while this line of research is far from conclusive, it is noteworthy that executive and prefrontal functioning are often found to be associated with particular creative cognitive skills. Furthermore, more substantial evidence has already been reviewed above documenting the associations between SES and executive and prefrontal functioning. Thus, the evidence from both lines of research is substantial enough to warrant an examination of the connections amongst all three constructs – particularly regarding how any relationships between SES and creative cognition might be mediated by executive and prefrontal functioning.

Creativity and Socioeconomic Status

Arguments have been made on largely theoretical and hypothetical grounds that creativity may be related to the immediate social and economic context in which a child develops. For example, in their review of what creativity research has revealed about the constraints that might be placed on creativity, Sternberg and Kaufman (2010) mentioned resource constraints. They presented the idea that children from lower income families or who have grown up in adverse environmental conditions may display a different type of creativity – not necessarily better or worse – than children from more affluent and less adverse upbringings; the opportunities to develop and demonstrate creativity may not be the same. Russ and Fiorelli (2010) emphasized the importance of play and child rearing conditions for the development of creativity in early childhood. Among others, Lareau (2011) has documented extensively how such developmental opportunities are unequally related to social class. As already noted, Kuhn and Holling (2009) used multilevel modeling in an educational context to explore divergent thinking. Importantly here, the contextual findings from their study, made possible by the multilevel modeling, suggested the importance of childhood SES. While they did not analyze the relationship between divergent thinking and student SES directly, they did note the importance of the classroom context (which is likely correlated with student SES), given their finding that divergent thinking performance varied meaningfully across classrooms in the study. In fact, one of their suggestions for future research was to more explicitly model and account for the social contextual influences in students' lives bearing on their divergent thinking and other creative abilities.

These theoretical arguments notwithstanding, there is limited empirical evidence suggesting any systematic connections between SES and creativity, particularly from a neurocognitive perspective. Several studies in the 1970s and 1980s explored certain aspects of an SES-creativity relationship. For example, in response to a perceived negative tone in testing research at the time due to issues surrounding testing bias, Torrance (1973) provided a checklist to help identify creative talent in historically disadvantaged populations, including minority students and students from lower SES backgrounds. In a review by Torrance (1971) published two years prior, he examined seven administrations of the Torrance Tests of Creative Thinking (TTCT) that also measured SES, yielding mixed findings. Certain subtests in some studies showed an advantage for higher SES students, some showed no difference, and still others showed an advantage for lower SES students, particularly on the verbal subtests.

Bashaw and White (1971) found that their sample of 277 low-SES kindergarteners performed at the norm for their age on the TTCT figural creativity tasks. Examining a creativity training intervention, Anastasi (1970) found evidence of its efficacy for only higher SES students. In the same study, in a section pertaining to the biographical correlates of creativity among high school students, many of the home environment factors which differentiated the creative from the non-creative are commonly associated today with SES (e.g., parental educational levels). Ward, Kogan, and Pankove (1972) found that student SES did not predict the psychometric properties of or fluency scores on their divergent thinking measures. In Milgram's (1981) examination of creative problem solving, she found that higher SES students were more likely to provide appropriate, novel, and original solutions to insight problems. Finally, in one other study of this time period, Haley (1984) examined socioeconomic status relative to creative response styles, or the modes of expressing responses to divergent thinking tasks. Higher SES students had higher fluency and originality scores using verbal expression, whereas lower SES students had better scores using kinetic expression and integrative expression. (Of note, all students in their sample were Black, so SES was not confounded by race. Such findings provide support for environmental – rather than heritable – influences on creative cognition.)

It is clear, however, that none of these research studies had the benefit of the state of contemporary neurocognitive knowledge to inform their pursuits. Creative cognition was not yet theorized and, if it even existed, neurocognitive knowledge regarding creativity was in its infancy. Furthermore, in getting at the broad question as to whether or not there may be a relationship between SES and creativity, these studies often under-theorized and inadequately measured SES. For example, though labeled SES in some studies, the construct was operationalized by a district or school indicator of disadvantage, such as participation in the NSLP. They often similarly equated creativity solely with divergent thinking. Another non-trivial concern with these studies is the explicit deficit language used in some of them. For example, one need only look to the title of Bashaw and White (1971)'s study: *Figural Creativity and Convergent Thinking Among Culturally Deprived Kindergarten Children*. Anastasi (1970) refers to the two levels of socioeconomic status in her study as "culturally disadvantaged and middle-class" (p. 27). As the learner profile, non-deficit view of creative cognition proposed here suggests, considering one group more disadvantaged – as opposed to having a different cognitive adaptation to their developmental environment – may be problematic for research and educational practice.

In a more recent study, employing a sample of 1,445 children, Dudek, Strobel, and Runco (1993) examined, among others, the relationships between figural and verbal performance on the Torrance Tests of Creative Thinking and SES. Their rationale for examining this relationship was based upon prior mixed findings regarding creativity and childhood SES (some of which have already been reviewed above). Further, they had aims similar to ours: namely, that if SES is an important consideration for creativity, it should be empirically demonstrated. They found a consistent positive relationship between SES and performance across all four divergent thinking scoring dimensions (i.e., fluency, originality, flexibility, and elaboration) on both verbal and figural versions of the test, and, while gender, grade, and SES all accounted for relatively little of the variance in divergent thinking scores overall, SES did explain more than the other two. Importantly, their study was limited to divergent thinking – not a larger battery of creative cognitive measures – and SES was conceived of as a group measure (i.e., low, middle, or high) at the school district level.

In an examination of possible ethnic differences in creative performance amongst a sample from Minnesota, Bart, Hokanson, Sahin, and Abdelsamea (2016) found differences in performance on the Torrance Tests of Creative Thinking Figural A version by race and ethnicity. Specifically, Black children in the sample scored lower than their White or Asian Pacific counterparts. Notably, the authors suggested that environmental differences – such as SES – could account for such differences, but student SES was not considered in this study.

Finally, in perhaps one of the most recent and relevant studies, Dai et al. (2012) explored the relationships between SES (as operationalized by NSLP participation at the district level and parental education at the student level) and three measures related to creativity: divergent thinking, self-reported creative personality traits, and self-reported perceptions of support for developing creative traits from teachers and parents. In their review of prior literature, they stated that not much work had been done on this particular question, perhaps because creative ability – unlike ELA or math achievement, for example – is normally only treated as an individual difference, as opposed to a possible group difference. However, they asserted that the potential policy implications for a creativity "gap" are perhaps as important as the long-standing inequalities in academic achievement. In their sample of 229 eighth graders, they reported evidence of differences in creativity by SES (for both their student- and district-level measures), specifically in terms of their composite measure of divergent thinking, which they concluded provides evidence for an SES-creativity "gap." Looking at possible mediators using stepwise regression, they also provided evidence that academic achievement and cognitive motivation may have mediated this relationship. A strength of this study was its ability to consider contextual SES influences by looking at both parental SES background *and* NSLP at the school district level.

However, while this study is an important step in investigating the relationship between SES and creativity, there are ways to improve upon it and further contribute to this area of inquiry. First, this study was conducted with an adolescent sample. There is ample evidence for other educational outcomes that relationships with SES are present earlier in childhood, and that earlier interventions might thus prove more fruitful. Similar research on a younger sample is needed here. Second, though they employed multiple measures contributing to a broad conception of creativity, these measures do not encompass all of what creativity is, even though the language employed by the authors often suggests that, nor do they seek to speak broadly to one aspect of creativity (e.g., a cognitive component). It is important to explicitly establish what part of the broad creativity construct is being measured, in a theoretically sound manner, in order to build upon and complement this research. Third, they only included parental educational attainment (dichotomized from four possible survey responses) as an indicator of student-level SES. While this is an important indicator, it is not recommended as a sole indicator, and so this measure can be improved upon by adding other indicators, such as household income and parental occupation.

Taken together, these studies demonstrate that there are mixed findings regarding SES and measures of creativity, as well as opportunities to improve and expand upon this foundation. These studies do not approach the relationships between SES and creativity from a neurocognitive framework, which might be a novel and beneficial approach by which to examine the topic and unpack the mixed findings to date. Further, the measures of creativity and SES were not consistently approached with an adequate theoretical base, matched with valid operationalizations that measured the particular constructs purporting to be measured.

Research Questions and Hypotheses

When we weaved these various research strands together, certain research questions and testable hypotheses, consistent with an overarching neurocognitive theoretical framework, emerges. On the one hand, student SES consistently predicts numerous educational outcomes, though the results concerning creativity are as of yet mixed. On a neurocognitive level, student SES predicts differential functioning in specific executive and prefrontal functions, *and* specific executive and prefrontal functions, in turn, are thought to underlie different aspects of creative cognition. Therefore, it is reasonable to explore the extent to which student SES ultimately predicts creative cognition through a neurocognitive lens, both on the basis that this is another important educational outcome for which evidence of any inequities should be demonstrated, and because there is neurocognitive evidence suggesting that executive and prefrontal functioning might mediate the influence of or interact with SES on creative cognition. Work exploring all three constructs simultaneously may lead to a richer understanding of the creative cognitive profiles of students from different socioeconomic environments.

Three research questions guided our extension and integration of these various research literatures.

1. *Does student SES predict the creative cognitive skills of associative processing, insight problem solving, or divergent thinking?* We hypothesized that there would be an overall positive relationship between SES and creative cognitive skills; though, there would be a different profile of creative cognitive strengths for students from different SES contexts.
2. *How are specific executive functioning skills related to each of the creative cognitive skills?* We hypothesized that the executive functioning skills of working memory, inhibitory control, and shifting would be differentially related to the creative cognitive skills: working memory would be positively related to all three creative measures, and cognitive control and shifting would be particularly important for divergent thinking and insight. That is, all three creative cognitive measures would depend upon the ability to hold and process information in consciousness; however, the abilities to inhibit prepotent ideas and flexibly shift to other ideas would be particularly important for having higher fluency and originality in divergent thinking, on the one hand, and moving past obvious solutions to arrive at insights, on the other.
3. *To what degree are relationships between student SES and each of the creative cognitive skills mediated by or in interaction with each executive skill?* We hypothesized that some of the variance in relationships between SES and each of the creative cognitive measures would be mediated by executive skills; though, the amount explainable for each creative cognitive skill would vary depending upon the differential recruitment of the executive skills, as illuminated in the answer to the prior question. Furthermore, we expected to see an even more complete, but

differential, creative cognitive profile in relation to SES than revealed in the answer to the first question.

Methods

Participants

In order to determine the appropriate sample size needed to detect the hypothesized SES associations with the cognitive variables, STATA 13.1 was used to conduct power analyses. Using regression analyses, Noble, McCandliss, and Farah (2007) found statistically significant beta values for SES predicting cognitive control and working memory of 0.23 and 0.24, respectively, with a total sample of 150 children. This study and these effects are fairly typical of other findings in the field. To detect a similar effect size, with 0.70 power at an alpha level of 0.05, a sample of approximately 110 participants would be needed.

We recruited from three different sources to obtain a targeted primary-aged sample of this size with the needed SES variability for this study. All were located in the Baltimore Metropolitan Area at the time of the study. Thirty-nine participants were recruited from a tuition-based summer program for advanced learners. These students generally represent a middle- to high-SES population, although financial aid is provided to some students. An additional 70 participants were recruited from an extracurricular enrichment program in under-resourced community public schools, designed for advanced learners. These students tend to have lower SES but represent the same high academic potential as the summer program students. Finally, 15 participants were recruited from the general community.

Though this sampling strategy, rooted in different program types, was designed to capitalize upon likely SES variability, we did not expect these different program types to yield a sample systematically different on other important variables that might affect our analyses of executive and creative cognitive skills. We did not hypothesize, for example, that program differences in variables unrelated to SES would differ systematically by program type *and* predict either executive or creative cognitive skills. We did hypothesize that common correlates of SES would differ by site, such as urbanicity or race and ethnicity; however, such variables are not here hypothesized to relate to executive or creative cognitive skills *apart from* their relationships with SES. While there is evidence that both executive and creative cognitive skills can be deliberately intervened upon and trained in order to improve performance (as was reviewed in the prior chapter), such interventions were not part of the curricula at either program type and we have no knowledge of their systematic, differential use. Indeed, one of the aims for the relatively newer extracurricular enrichment program was to provide content and development opportunities similar to those that have been provided for much longer historically in the tuition-based summer programs.

Seventeen participants (11 enrichment, three summer, and three community) were excluded. One observation was removed *a priori* because this participant was 15 years of age, whereas the remainder of the sample was between the ages of seven and 13 – the range associated with primary education which is the focus of this investigation. The other 16 participants excluded from analyses were removed because they were missing observations on measures crucial to answering the research questions. Fourteen participants were missing all three indicators of SES[1], one participant was missing a Digit Span Backwards score, and one participant was missing a Symbol-Digit Modalities score. This yielded a final analytical sample of 108 participants.

Measures

To help guide the discussion of measures and analyses, Table 3.1 organizes the constructs studied and the measures operationalizing those constructs.

[1] Additional analyses were conducted to see if these 16 students were different in important ways from the remaining students (see Appendix B). Other than a small to moderate relationship between age and being excluded, no significant relationships were found.

Table 3.1
Constructs and Measures

Construct		Measure(s)	Possible score range
Socioeconomic status		Guardian survey	NA
Executive functioning			
	Working memory	Digit Span Backwards task	0 – 9
	Cognitive control	Go-No-Go task	0 – 10
	Executive shifting	Color-Shape Shifting task	NA
Creative cognition[a]			
	Divergent thinking	Instances task	NA
		Unusual Uses task	NA
	Insight	Insight word problems	0 – 4
		Remote Associates Test items[b]	0 – 16
		Word scramble items	0 – 16
	Associative processing	Letter and category task	0 – 26
Demographics and controls			
	Demographics	Student survey	NA
	Processing speed	Symbol-Digit Modalities task	0 – 110

Note. NA = not applicable to these measures since there were not predefined possible ranges. [a]All creative cognitive measures were contained within a single battery packet, the Flexibility in Thinking (FIT) measure; [b]Remote Associates Test items likely also tax associative processing and so, while they are categorized under insight, there is likely cross-over in also indicating associative processing.

C**reative cognition.** The Flexibility in Thinking (FIT) measure, crafted at our research lab, contains verbal measures of associative processing, divergent thinking, and insight, and it was used to assess the creative cognitive skills being studied here. This paper-and-pencil measure was first piloted on children with participants from both day-site and after-school programs during the summer and fall of 2015. There are two parallel forms, such that the format (e.g., number of items, item types, etc.) is the same, while the content of the items differs on each form.

Divergent thinking Instances and Unusual Uses tasks. Two types of items from the FIT were used to measure DT. There is an Instances item (e.g., “Name all of the square things that you can think of”) and an Unusual Uses item (e.g., “Name all of the uses for a brick you can think of”). In an examination of reliability of scoring methods for different types of DT tasks, Silvia (2011) found Unusual Uses tasks to be the most reliable, followed by Instances tasks, which were moderately reliable, employing the maximal-reliability *H* statistic with subjective scoring (i.e., responses were assessed by raters, as opposed to objective scoring, in which responses might simply be counted or compared for relative frequency within the sample). Each participant was presented with two DT items, one of each of these types. Participants completed each item separately, with two minutes to complete each. Participants were explicitly instructed to come up with as many unique answers to each prompt as possible, and, because this was explicitly instructed, these tasks were likely well-suited to capture maximal DT skills, as opposed to typical skills (Silvia, 2011; Silvia, Martin, & Nusbaum, 2009). That is, the participants were explicitly told to try to be unique, which is thought to measure something different than when the instructions to the task simply ask participants to generate responses.

Researchers have proposed many different methods for scoring DT tasks (e.g., Kaufman, Plucker, & Russell, 2012; Plucker & Makel, 2010; Plucker, Qian, & Wang, 2011; Silvia, 2011; Silvia, Martin, & Nusbaum, 2009). As noted already, these tasks are typically scored along any of four dimensions: fluency, originality, flexibility, and elaboration. Runco (2010) notes the importance of including as many of these dimensions in a research study with DT as possible because each may provide somewhat unique information; other researchers note the high correlation between fluency and originality as a justification for solely using one or the other. For this study, participants' responses were scored for fluency and originality to balance including multiple information points regarding participant DT skills with the efficiency of objective scoring (which, as is described further below, would be considerably less efficient with the inclusion of the other two dimensions). In particular, scoring a category dimension would introduce a substantial amount of subjectivity to the dataset at a particularly high cost to the practicability of completing the study in a timely manner. There are also far fewer examples of category scoring available in the empirical literature upon which to build.

Several replicable steps were taken in order to prepare participants' pencil-and-paper responses for fluency and originality scoring. First, any duplicate responses within a participant's response set for a specific item were removed. For example, if in response to the circle Instances prompt a participant wrote "ball" twice, only one was counted. A second category of data cleaning included removing the words "the," "a," "an," as well as "to" and "as" when they led any of the unusual uses responses. For example, a response of "to break a piece of glass" in response to the Unusual Uses for a brick prompt would become "break piece of glass." A response of "a circle" for the round Instances prompt became "circle." There were a few instances in which the entire response was surrounded in parentheses; these were removed. Symbols used in place of words (e.g., "#" instead of "number") were changed to their word equivalent. Finally, responses were corrected for spelling and capitalization, and compound words were standardized to match use throughout (e.g., "head phones" and "headphones" were both standardized as "headphones").

Table 3.2 quantifies the extent to which responses were standardized due to each of the abovementioned procedures. This table shows that almost 80% of the responses provided by participants were analyzed as originally written by the participant. All of the responses provided by 18 participants were analyzed as written. An additional 39 only needed one or two responses transformed. On the high end of the transformation range, six participants required between ten and 16 transformations. Of the remaining fifth of responses requiring some sort of transformation prior to analysis, the largest category consisted of corrections for spelling (as might be expected for the age of this sample), followed by the combination of removing the words "a," "an," "the," or "to" from responses.

Table 3.2
*DT Response Standardization Statistics for All Responses (*n *= 2,116)*

Type of Response Transformation		Count	Percentage
None – analyzed response matched participant's original		1,682	79.49%
One transformation from original to analyzed response			
	Compound standardization	28	1.32%
	Parentheses surrounding entire response removed	1	0.05%
	Punctuation corrected	4	0.19%
	"a" removed from response	93	4.40%
	"an" removed from response	3	0.14%
	"the" removed from response	12	0.57%
	"to" removed from beginning of response	43	2.03%
	Spelling corrected	188	8.88%
	Symbol transformed to word form	1	0.05%
Two or three transformations needed to arrive at analyzed response		61	2.88%

Note. One other category not represented in any of the one-transformation responses but included in those responses needing two or three transformations was Capitalization (e.g., proper nouns). It was frequently the case that a participant misspelled and did not capitalize a proper noun, such as "Rubick's Cube" – a particularly popular choice for the square Instances item.

All of these steps were taken because they could be easily replicated as an objective method of scoring these DT tasks and they seemed to get at the essence of differentiating answers beyond superficial distinctions (e.g., the presence or absence of "a"). Resulting responses were judged for their appropriateness in addressing the prompt by considering response completeness (i.e., whether or not a complete word or thought was expressed) and a liberal threshold for being deemed appropriate (i.e., the above procedures resulted in a response that could be corrected). These criteria resulted in 16 responses – 0.76% of all responses – not marked as appropriate (and thus excluded from subsequent scoring) by 14 participants.

Once the DT responses were in a scoreable form, we calculated each participant's fluency score as the sum of their appropriate responses on each item. Then, following Plucker, Qian, and Wang (2011), originality was scored according to a percentage method. This method was chosen in an attempt to isolate originality from fluency as much as possible, while simultaneously maximizing validity and reliability.

Per the subjective-objective distinction noted above, this is considered an objective way of scoring originality. Each response from each participant was given one point if it was provided by less than 5% of the sample and zero points otherwise. Then to arrive at an originality percentage that attempted to control for the influence of fluency, the participant's total originality points were divided by their total fluency score to arrive at their final originality score. This method of evaluating subjects' originality is dependent upon sample size – an oft-cited criticism, however, given the exploratory nature of the research and the moderate sample size, this should not be a major concern, particularly in conjunction with fluency also being considered (Silvia, Martin, & Nusbaum, 2009).

Insight Problems. There was a set of four insight problems (i.e., riddles, or "brain teasers") in order to assess insight. Participants had four minutes to complete as many as possible, with each correct response given one point.

Remote Associates Test items. A set of 16 items mirroring items from the Remote Associates Test (RAT; Mednick, 1962) were used to assess both insight and associative processing. These items consisted of three words that were superficially unrelated but could be connected by the relation of each to a fourth word. As an example, an item might have the three words "political / surprise / line" with the correct response being "party" (i.e., political *party*, surprise *party*, and *party* line). Participants were given three minutes to complete as many as possible, with each correct response given one point.

Word Scramble items. Sixteen word scramble items were used to assess insight. Each problem consisted of one word with the letters arranged out of their proper order, and the participant had to write the word with the letters arranged in the correct order (e.g., "tebl" might become "belt"). Words were selected from the level one (roughly equivalent to first grade) assessments of the Qualitative Reading Inventory-5 (QRI-5; Leslie & Caldwell, 2011) in order to ensure that the words would be recognizable for this age group; that is, this method of choosing words should mean that familiarity with the unscrambled words would be less of a confound for task performance. Participants were given three minutes to complete as many as possible, with each correct response given one point.

Alphabetical-Categorical fluency task. To assess associative processing, an item containing 26 answer response spaces, one beginning with each letter of the alphabet, was given to the participant. One version of the FIT asked the participant to fill in as many response spaces as possible with fruits or vegetables and the other version asked for animals. This task captures both phonetic and category fluency (e.g., Lee & Therriault, 2013).

Digit Span Backwards task. A Digit Span Backwards task (modeled on the Digit Span task from Wechsler, 2014) was used to assess working memory, in which each participant was read aloud a sequence of numbers and then was asked to repeat those number back in reverse order, thus requiring short-term memory of the numbers *and* the ability to manipulate the numbers simultaneously. There was a practice trial with two 2-digit sequences and then the part of the task that was scored began with two 4-digit sequences. The largest sequence correctly repeated back was the participant's score. The task ended when two sequences of the same length were both incorrectly recalled backwards.

Go-No-Go task. A computerized Go-No-Go task assessed inhibitory control, designed based on the description of the task used in Noble, McCandliss, and Farah (2007). This task took about one minute to complete and consisted of animal pictures appearing on the computer screen once every second. The participant was asked to press the space key as fast as possible every time she saw an animal – unless that animal was a dog. In total, 60 animals randomly appeared on the screen, 10 of which were dogs. The score used for this task was the number of times the participant did not strike the space key when the dog appeared. Thus, a higher score represents greater inhibitory control because this indicates the number of times the participant inhibited a dominant response (i.e., pressing the space bar with the appearance of every other animal besides the dog).

Color-Shape Shifting task. To capture executive shifting ability, we adapted a test from Mittal and colleagues (2015), in which shifting ability is operationalized as the difference between the time it takes a participant to repeat a task and the time it takes the participant to shift to a different task. This computerized Color-Shape task proceeded as follows. The participant was presented with a series of trials on a computer screen. At the top of the screen in each trial was a word indicating the category type (i.e., shape or color) and underneath this word was a colored shape. The shape was either a circle or a triangle and the color was either red or green. Using two keyboard keys – one with a patch of red and the black outline of a circle on a white background, the other with a patch of green and the black outline of a triangle on a white background – the participant was tasked with categorizing the colored shape according to the category word at the top of the screen. For example, if the top of the screen read “SHAPE,” the participant would hit the key corresponding to a circle or triangle, disregarding its color. But, when the category label changed to “COLOR,” the participant had to pick the key with the color that matched the shape, disregarding the shape. A repeat trial was one in which the category was the same as the prior trial, whereas shifting trials were those with a different category from the prior trial. The average difference in response times between accurate responses on these types of trials is thought to suggest the participant’s ability to flexibly shift between category types. The smaller the difference in average response times between these trial types, the greater the executive shifting ability and flexibility the participant is thought to possess.

Guardian survey. We collected several indicators of SES from participants’ guardians using a brief, pencil-and-paper survey, which included items asking about the following for all guardians in the household: educational attainment level (i.e., the highest degree or certificate completed), work status (e.g., full-time or part-time), and occupation. Additionally, there were items requesting total household income in 2015, the total number of people living in the household, and the total number of people living in the household under the age of 18. Occupations were coded for prestige according to the scale created by Smith and Son (2014), which is based upon the 2012 General Social Survey. The occupational prestige scores were based on respondents of that scale choosing a perceived prestige rating for an occupation on a scale from one to nine.

Demographic and control variables. In order to understand the demographic composition of our sample, as well as to better qualify the relationships amongst SES, executive functioning, and creative cognition, several demographic variables and covariates were considered. There is prior theoretical and empirical work to suggest that some of these variables need to be considered when examining the key constructs in this research.

Symbol-Digit Modalities task. Researchers using some of the cognitive measures here have noted that processing speed plays an important role in task performance on timed tasks (e.g., see the review in Kuhn & Holling, 2009), and several of the creative cognitive measures here were timed. So, processing speed was assessed using a Symbol-Digit Modalities measure (Smith, 1973) in which participants had 90 seconds to orally complete a sequence of symbols with their corresponding numbers based on a key. The greater the number of correct responses, the greater the processing speed score.

Student survey. There is some evidence that certain demographic variables may be related to creativity or SES, and thus could account for any relationships found here between these constructs: multilingualism (e.g., see the review in Lubart, 2010), gender (e.g., Kuhn & Holling, 2009), age and grade level, race and ethnicity (e.g., to avoid construct confounding effects; Shadish, Cook, & Campbell, 2002), handedness (Shobe, Ross, & Fleck, 2009), and program type (e.g., the immediate testing context may impact divergent thinking performance; Kuhn & Holling, 2009). Therefore, to address possible confounding influences and seek to describe our participants, a student survey was used to capture student self-responses about each.

Procedures

This study was approved by the Homewood Institutional Review Board (HIRB) at Johns Hopkins University. Guardian permission and participant assent was collected for every participant prior to participating in the study. Guardians of the enrichment, school-based participants provided permission for their child's participation as a part of program admission. All other guardians provided permission when their child was recruited. For all parents and guardians, at the time we obtained permission, we also asked them to complete our questionnaire assessing SES.

The participant measures (i.e., the demographic questionnaire, as well as those assessing executive functioning, creative cognition, and processing speed) were completed in individual sessions lasting about 40 minutes. The assessment battery proceeded as follows. The participant was escorted to a room, in which up to two other participants were simultaneously being tested. Each participant was assessed one-on-one with a researcher. Every participant began by completing the demographic survey. Participants were then presented with each of the cognitive tasks in the battery. As described in greater detail above, the tasks either required the participant to write responses on paper, provide oral responses which were recorded by the researcher, or input responses using an Apple laptop computer keyboard.

Tasks were presented in randomized order; however, for an early subset of participants, researchers were given latitude to adjust the order based on the testing conditions. This practice of adjusting order was eliminated partway through the study, and all participants were flagged based on whether or not the order was random. Out of 108 participants, 61 (56.48%) did the tasks in a random order (see Table 3.3). Two-sample t-tests on task performance were used to determine whether those that deviated from random differed from the fully randomized group. These tests were conducted for each of the key study variables. None of the tests were statistically significant at a liberal alpha level of 0.05, so task order was not included in further analyses.

Table 3.3
Proportion of Program Types Receiving Randomized Task Order

	Randomized	Not randomized
Enrichment	33	26
Lab	6	7
Summer	22	14

Upon completing the assessment battery, eligible participants were thanked for their participation and given a $10-giftcard or toy of comparable value. Students in the extra-curricular program were not eligible for additional incentives because the testing was part of the program which was already viewed as a benefit.

Statistical Analyses

The discussion of statistical analyses is broken into four sections: descriptive analyses and preparing the analytical dataset; followed by three sections addressing each of the three research questions, respectively. All analyses were conducted using Stata IC version 13.1, and a study-wide *p*-value of 0.05 was established *a priori* to determine the statistical significance of all results. However, because we conducted a relatively large amount of statistical tests due to the multiple stepwise regression strategy, coupled with the number of dependent variables being regressed, each stepwise regression model is also corrected with a family-wise error rate based upon the number statistical tests. This was done in order to protect against Type I errors, or the possibility of finding statistically significant results as a product of estimating enough statistical parameters – not because the parameter is actually likely to be significant in its own right. As an illustration, in a set of stepwise models examining the predictive relationships between SES, covariates, and one of the creative cognitive variables, we assess the statistical significance of three covariates in both steps, SES in one step, adjusted R^2 values in both models, and the change in adjusted R^2 values – a total of 10 estimates of statistical significance with which we are concerned. Thus, for this particular model, we would determine whether or not an estimate was statistically significant by dividing our study-wide rate of 0.05 by the 10 parameters, resulting in a rate of 0.005. Of note, we used alpha levels of 0.05 – and not corrected values – for tests of random task order effects or inclusion of covariates, reasoning that a higher alpha level for these tests would favor inclusion of any of these important variables that may impact the stepwise regression results.

Descriptive analyses and preparing the analytical dataset. We first present descriptive statistics for all variables, including means, standard deviations, ranges, and paired correlations. The correlations provide the first bits of evidence for (binary) relationships among the constructs of interest, as well as justification for creating any composite variables and the inclusion of covariates in subsequent models.

Does student SES predict the creative cognitive skills of associative processing, insight problem solving, or divergent thinking? The essence of answering this first research question is determining whether or not SES predicts each of the creative cognitive skills – after controlling for select covariates. To statistically address this – and each subsequent – question, stepwise regression methods were used. Here, we estimated a series of two-step regression models, one for each distinct creative cognitive skill. In the first step of each model, the creative cognitive skill was regressed solely on SES. In the second step, we added covariates. Interpretations of these models focus on the total variance of each creative cognitive skill explained by SES, as well as to what degree the control variables may account for any relationships. Also, the significance and magnitude of the regression coefficients are interpreted. Importantly, in each series of models, the suggestion of any mediation will be investigated by examining if any coefficients from key variables in earlier step models decrease with the addition of variables in a subsequent step.

How are working memory, inhibitory control, and shifting related to each of the creative cognitive skills? The analysis strategy here mirrors that from the previous research question. Each of the creative cognitive skills was regressed on the executive functioning measures in two-step models with covariates added in the second step.

To what degree are relationships between student SES and each of the creative cognitive skills mediated by or in interaction with each of executive skills? The final research question was aimed at determining the extent to which any relationships between SES and creative cognitive measures uncovered in the first research question might be mediated by executive skills. One way of conceptualizing the analyses for this research question is to essentially combine what was done for research questions one and two. Therefore, we continued using the stepwise analytical technique when addressing this question, though, the content of the two steps changed: the first re-stated the relationships already noted above between SES, the covariates, and the creative cognitive skills for which significant models were identified. The second step added the three executive skills to demonstrate whether or not any of them explained some of the variance accounted for by SES and the covariates.

Going one step further, this question was also about the profile of executive skills, by student SES, predicting each of the creative cognitive skills – something a bit different than mediation, indeed a moderation or interaction. This way of looking at the question gets at the core of the learner profile, non-deficit approach by considering how student SES and executive skills may interact to predict the creative cognitive skills here. Put another way: is it possible that students from different socioeconomic backgrounds have different profiles of executive skills predicting different profiles of creative cognitive skills? To address this, a series of *three*-step regression models were estimated. In the first step of each stepwise regression model, SES and each executive skill were regressed on one of the eight creative cognitive skills. In the second step, interaction terms between SES and each of the executive skills (i.e., three additional terms; SES x working memory, SES x shifting, and SES x inhibitory control) were added. In the final step, the covariates were entered.

Results

Descriptive Statistics for Demographic, Control, and SES Measures

The sample had a mean age of 9.81 years, ranging from seven to 13. Table 4.1 provides descriptive statistics for the nominal demographic variables captured on the student survey. A slight majority of participants came from the after-school enrichment program (54.63%), with the balance coming from the summer day programs or recruited to our lab from the community, a roughly even split confirming our recruitment strategy was likely to provide the needed socioeconomic variance. Indeed, given the oft-noted relationship between SES and race and ethnicity, a second suggestion of some success in our recruitment strategy is shown by the race and ethnicity of our sample: most notably, 37.04% Black or African American, 29.63% White, and 14.81% Asian. Given the frequent mention of multilingualism in creativity-related research, it is also noteworthy that nearly a fifth of our sample (19.44%) self-reported speaking a language other than English fluently.

Table 4.1
Descriptive Statistics of Participant Sample

	Count	%
Program Type		
Enrichment	59	54.63%
Lab	13	12.04%
Summer	36	33.33%
Multilingualism		
Participant answered “no”	87	80.56%
Participant answered “yes”	21	19.44%
Gender		
Female	56	51.85%
Male	52	48.15%
Race and Ethnicity		
Hispanic	2	1.85%
American Indian or Alaska Native	2	1.85%
Asian	16	14.81%
Black or African American	40	37.04%
Native Hawaiian or other Pacific Islander	0	0.00%
White	32	29.63%
Multiple Selected	15	13.89%
No Response	1	0.93%
Handedness		
Both	4	3.70%
Left	6	5.56%
Right	98	90.74%

Table 4.2 shows descriptive statistics for the numerical or numerical-transformed items from the guardian survey. The mean household size was about 4 people (M = 4.15) with about 2 (M = 2.10) of those people being under the age of 18. Guardians were given different category options for reporting total household income, ranging from “below $25,000” to “above $200,000”, with five other range options in between. These options were all collapsed to their midpoint values (or their stated values for

the two extremes) for ease of analysis. Using these midpoint values for analysis, we found mean household income for the 77 respondents that provided this information (M = \$122,402.60; SD = \$68,415.38) to be bimodally distributed: about 42% of the sample reported \$150,000 and above, whereas about 24% reported \$50,000 or below (see Figure 1).

Table 4.2
Descriptive Statistics for Continuous Items on Guardian Survey

	n	M (SD)	Range
People in household	87	4.15 (1.01)	2 – 7
People under 18	86	2.10 (0.84)	1 – 6
Household income[a]	77	\$122,402.60 (\$68,415.38)	\$25,000 – \$200,000
Highest guardian occupation prestige	96	5.88 (1.06)	3.00 – 7.60

Note. n = number of respondents; M (SD) = mean and standard deviation; [a]responses for this measure were transformed to the mean of the salary range selected by the guardian.

For occupational prestige and educational attainment, only the highest guardian score on each is described since only these were used for analyses. The average occupational prestige in our sample (M = 5.88; representing, e.g., a Business Entrepreneur, Computer Network Engineer, or Public Grade School Teacher) falls slightly above the middle of the scale used to code prestige. The range in our sample (3.00 – 7.60) is represented by a Stockroom Attendant at the low end and a Physician at the high end.

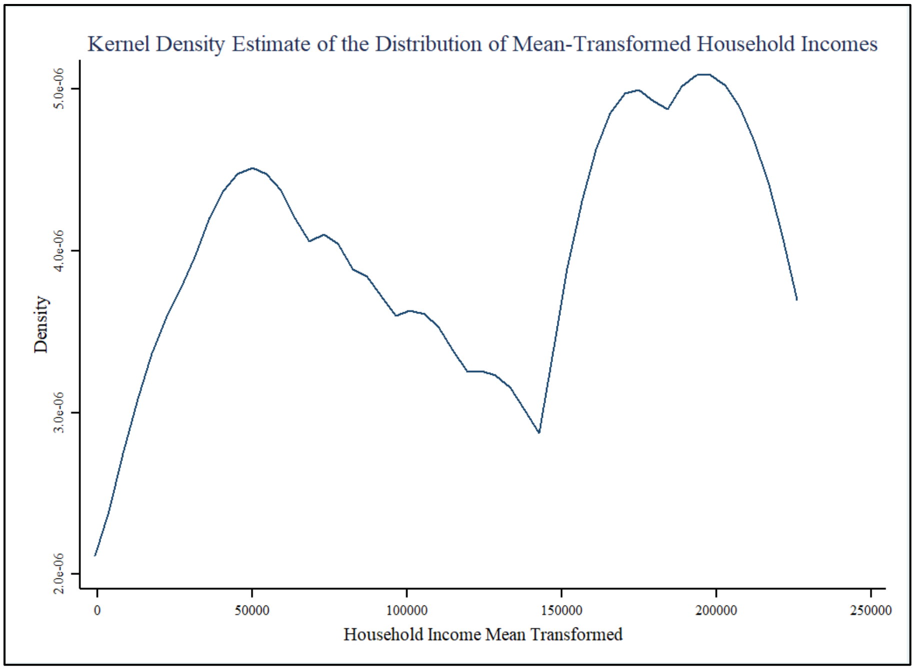

Figure 4.1. Epanechnikov kernel density plot of mean-transformed household incomes.

Table 4.3 shows the highest guardian educational attainment for the households in our sample. The vast majority of the students' guardians in this sample were well-educated, having attained a Bachelor's degree or more. For ease of analysis, each of the attainment levels was coded as years of education (the coded years for each level is shown in parentheses in Table 4.3). This coded years of education variable had a mean of 16.54 (*SD* = 3.08; [10 – 20]), suggesting the average highest household educational attainment by guardians in our sample was college-level.

Table 4.3

Observed Frequencies of Educational Attainment Categories and Coded Number of Years for Analysis

	n	% of item respondents
Highest guardian education (coded years)		
Some high school (10)	2	1.85%
GED certificate (11)	1	0.93%
High school diploma (12)	11	10.19%
Associate degree (14)	2	1.85%
Vocational degree	0	0.00%
Some college (13)	17	15.74%
Bachelor's degree (16)	21	19.44%
Master's degree (18)	21	19.44%
Doctorate degree (20)	12	11.11%
Professional degree (20)	17	15.74%
Doctoral and Professional degrees (20)	4	3.70%

Note. n = number of respondents.

Creating an SES Composite

Following common practice and established recommendations for analyzing SES (e.g., Cowan et al., 2012) we examined three of the above indicators: highest guardian educational attainment, highest guardian occupational prestige, and household income. These three indicators were highly interrelated in this sample, with the lowest correlation between any two being $r = 0.69$ and the highest being $r = 0.72$. Thus, all three were combined into a composite. To create the composite variable, we first standardized these three indicators to have means of zero and standard deviations of one.

Seventy-one participants had observed values for all three indicators. The composite for these participants had a mean of 0.45 ($SD = 2.54$; [-6.04 – 3.83]). However, in order to maximize statistical power for these analyses, we examined the possibility of including an additional 37 participants in our sample that had at least one indicator of SES, but not all three. Rather than combining linearly, this composite is an *average* of whichever indicators were observed ($M = -0.09$; $SD = 0.92$; [-2.08 – 1.28]). The distributions of both of these composites were similar upon visual inspection. More importantly, correlations between each of these SES measures and other key study variables demonstrated similar relationships; all of the coefficient magnitudes and ordinalities were similar. Therefore, we used the average-based composite moving forward in order to maximize our analytical sample.

Relationships Among Key Study Variables

Table 4.4 provides means, standard deviations, and ranges, and Table 4.5 provides pairwise correlation coefficients for key study variables. To help guide the reader through the correlation coefficients, interpretations will move from left to right across columns, and from top to bottom, starting with the correlations between the SES composite and other variables. It is important to note that these correlation coefficients were not corrected for multiple comparisons since the object here was to begin to describe and explore the data, not answer any of our key research questions. The only analytical decisions we made based upon these correlations were whether or not to create composites. Here, the significance of the coefficients is less important than their magnitudes; the size of the coefficients suggests an effect size and can point towards any issues of collinearity – both important considerations where determining how closely related different measures may be.

Table 4.4
Means, Standard Deviations, and Ranges for Key Study Variables

	Mean (*SD*)	Range
SES Composite	-0.09 (0.92)	-2.08 – 1.28
Digit Span Backwards	4.76 (1.41)	2 – 8
Go-No-Go	7.67 (1.47)	4 – 10
Color-Shape Shifting[a]	249.54 (427.18)	-2501.74 – 1565.15
Alphabetical-Categorical Fluency	11.44 (4.52)	3 – 23
DT Instances – Fluency	10.05 (4.02)	3 – 21
DT Instances – Originality[b]	0.50 (0.23)	0 – 1
DT Uses – Fluency	6.94 (2.69)	2 – 17
DT Uses – Originality[b]	0.72 (0.21)	0 – 1
Insight Problems	1.13 (1.15)	0 – 4
Remote Associates Test	3.48 (2.80)	0 – 12
World Scramble	9.47 (3.29)	2 – 16

Note. SD = standard deviation; SES = socioeconomic status; DT = divergent thinking; [a]measured in milliseconds as the cost associated with shifting attention; [b]originality was calculated via a percentage method (student's fluency on that item being the denominator).

As Table 4.5 shows, higher SES was significantly associated with higher performance on the Digit Span Backwards task ($r = 0.27$), but not with either of the other two measures of executive functioning, the Go-No-Go ($r = 0.07$) and Color-Shape Shifting ($r = -0.04$) tasks. In contrast, SES was significantly related to five of the eight creative cognitive measures. The highest of these significant associations was $r = 0.39$ with the RAT items and the lowest was $r = 0.20$ with the DT Instances Originality score, in all cases suggesting higher task scores for higher SES participants.

Table 4.5

Correlation Coefficients for Key Study Variables

	SES Composite	Digit Span Backwards	Go-No-Go	Color-Shape Shifting	Alphabetical -Categorical Fluency	DT Instances – Fluency	DT Instances – Originality	DT Uses – Fluency	DT Uses – Originality	Insight Items	Remote Associates Test	Word Scramble
SES Composite	1.00											
Digit Span Backwards	0.27*	1.00										
Go-No-Go	0.07	0.07	1.00									
Color-Shape Shifting[a]	-0.04	0.01	0.11	1.00								
Alphabetical-Categorical Fluency	0.36*	0.28*	0.10	-0.03	1.00							
DT Instances – Fluency	0.09	0.09	0.08	0.03	0.34*	1.00						
DT Instances – Originality[b]	0.20*	0.13	-0.10	-0.11	-0.04	0.08	1.00					
DT Uses – Fluency	0.23*	0.03	-0.02	-0.03	0.23*	0.42*	0.15	1.00				
DT Uses – Originality[b]	-0.02	-0.14	0.05	-0.05	0.04	0.15	-0.14	0.30*	1.00			
Insight Items	0.34*	0.18	0.08	-0.13	0.30*	0.22*	0.15	0.16	0.16	1.00		
Remote Associates Test	0.39*	0.39*	-0.07	-0.08	0.42*	0.27*	0.15	0.24*	-0.03	0.55*	1.00	
World Scramble	0.11	0.21*	0.04	-0.15	0.27*	0.30*	0.18	0.07	-0.05	0.44*	0.42*	1.00

Note. SES = socioeconomic status; DT = divergent thinking; [a]measured in milliseconds as the cost associated with shifting attention; [b]originality was calculated via a percentage method (student's fluency on that item being the denominator).

* $p < 0.05$

The measure of working memory – Digit Span Backwards – has already been noted for its significant association with SES. Further, it was not related to either of the other two executive functioning tasks (*r*'s of 0.07 and 0.01). Greater working memory capacity was significantly associated with greater performance on three of the creative cognitive measures: Alphabetical-Categorical Fluency ($r = 0.28$), RAT items ($r = 0.39$), and Word Scramble items ($r = 0.21$). The other two measures of executive functioning have already been noted for their lack of any significant associations with SES and the measure of working memory; additionally, there were no significant relationships between either Go-No-Go or Color-Shape Shifting and any of the creative cognitive variables.

Alphabetical-Categorical fluency has already been distinguished for its relationship with SES and Digit Span Backwards. Higher associative processing scores were also significantly related to higher performance on most of the other creative cognitive measures. Specifically, there were relationships with both DT fluency measures ($r = 0.34$ and $r = 0.23$ for Instances and Uses, respectively), as well as with Insight problems ($r = 0.30$), RAT items ($r = 0.42$), and Word Scramble items ($r = 0.27$). The two creative cognitive measures with which associative processing was not related were both of the DT originality scores.

The two DT fluency measures were moderately related to one another ($r = 0.42$), with higher performance on one associated with higher performance on the other. Only one of these was related to either of the DT originality scores; higher Uses Fluency scores were significantly related to higher Uses Originality scores ($r = 0.30$). Instances Fluency was significantly associated with Insight problems ($r = 0.22$), RAT items ($r = 0.27$), and Word Scramble items ($r = 0.30$), whereas Uses Fluency was only related to RAT items ($r = 0.24$); though, in all of these instances, higher fluency scores were associated with higher RAT performance.

The findings for the DT Originality scores stand in contrast. They were not significantly related to each other, nor to Insight problems, RAT items, or Word Scramble items. Indeed, the only significant association with another creative cognitive measure was that mentioned above between Uses Fluency and Uses Originality. To reiterate a finding mentioned above, the Instances Originality score was also the lowest significant relationship between the SES composite and a creative cognitive measure. The findings noted in this paragraph and the prior paragraph suggest that DT scores and tasks cannot be combined into composites in subsequent analyses. Instead they should remain separate indicators due to their relatively distinct patterns of associations with other variables in the study, as well as inconsistent intercorrelations.

Last, the relationships relevant to the insight measures (and associative processing in the case of the RAT items) – which have all been mentioned above – can be summarized as follows. Two of the three, Insight problems and RAT items, were significantly associated with SES. A distinct pair – RAT and Scramble items – were significantly related to working memory performance. All three were related to at least half of the creative cognitive measures, and, finally, all three were moderately correlated with one another, suggesting that higher performance on one will predict higher performance on the other two (though, the relationship between Insight problems and RAT items (r = 0.55) was particularly strong).

Selecting Covariates

To determine which covariates would be included in subsequent analyses and which would be excluded, pairwise correlations were examined between each of the hypothesized covariates and the key study variables using a liberal alpha level of 0.05. Multilingualism and processing speed were retained for subsequent analyses because both multilingualism and processing speed were significantly related in the hypothesized (positive) direction with four of the creative cognitive variables, the SES composite, and working memory. Age was also included because of significant associations in the hypothesized (positive) direction with Insight problems, RAT items, and Word Scramble items. Gender was not related to any of the key study variables and handedness only had one significant relationship in a non-hypothesized direction (right-handedness predicted *better* outcomes on the creative cognitive variables), so neither of these were included.

The Decision to Exclude Program Type and Race and Ethnicity

The following race and ethnicity categories were not significantly related to any key study variables: Hispanic, American Indian or Alaska Native, Native Hawaiian or other Pacific Islander (alpha level of 0.05). There were, however, several significant relationships in directions hypothesized – given the aforementioned intertwined nature of race and ethnicity and SES – between selecting Asian, Black or African American, or White and key study variables – particularly SES, though also working memory and several of the creative cognitive variables. Indeed, pairwise correlations between SES and selecting Asian, White, or Black or African American were $r = 0.27$, $r = 0.51$, and $r = -0.60$, respectively, suggesting our Asian and White students to have higher composite SES scores than their Black or African American counterparts.

Unsurprisingly given the observed race and ethnicity disparities across different program types (35 of the 59 students from an enrichment program were Black or African American; 34 of the 49 students from summer or lab recruitment were White or Asian), there is a similar finding for program type. Specifically, students recruited from a summer day program ($r = 0.46$) or to our lab ($r = 0.27$) tended to have a higher SES, whereas students recruited from the after-school enrichment programs tended to have a lower SES ($r = -0.61$). Both summer program and enrichment program participation also had several significant positive and negative relationships, respectively, with several of the key cognitive variables under investigation. Table 4.6 illustrates this as well. For further evidence of the similar results obtained if the subsequent analyses used program type as opposed to SES as an independent variable, see Appendix A.

Table 4.6
Means and Standard Deviations for the Three SES Indicators by Program Type

	Enrichment	Lab	Summer
Highest guardian education attainment[a]	14.75 (2.81)	18.92 (1.93)	18.61 (1.64)
Highest guardian occupation prestige	5.46 (1.10)	6.36 (0.89)	6.38 (0.75)
Household income[b]	\$76,515.15 (\$55,177.06)	\$160,576.90 (\$60,562.93)	\$155,241.90 (\$55,506.59)

Note. *n* = number of respondents; *M* (*SD*) = mean and standard deviation; [a]responses for this measure were coded to number of years based on the education level selected by the participant; [b]responses for this measure were transformed to the mean of the salary range selected by the guardian.

As one final demonstration of the strongly intertwined nature of SES, program type, and race and ethnicity in this sample, SES was regressed on binary indicators for the three program types and the race and ethnicity categories just mentioned. These six indicators predicted over 46% of the variance in SES (*adj.* $R^2 = 0.46$). Anecdotally, these intercorrelational findings were expected. The after-school enrichment programs were designed to provide talent development experiences to urban students in under-resourced communities who might otherwise not be able to afford such experiences. Students attending summer day sites in affluent suburban areas generally paid a non-trivial out-of-pocket expense in order to attend. Indeed, as described in the *Participants* section above, we specifically targeted our recruitment in these different contexts in order to maximize our chance of having adequate variability of SES to detect any possible relationships with our cognitive variables of interest. This provides evidence that our recruitment strategy was successful.

So, though highly intertwined, both variables were removed from further consideration for two reasons. First, their inclusion would deter from answering the central questions concerning SES relationships. Both race and ethnicity and program type covary to such a high degree with SES and other cognitive variables that the variance shared between SES and the cognitive variables may effectively be controlled out of the models if the variance shared by SES, program type, and race and ethnicity were accounted for statistically. Second, there are not any strong theoretical precedents for doing so in relation to the cognitive variables being examined, particularly in the case of race and ethnicity.

Socioeconomic Contrasts Across Key Study Variables

Before moving to the relative complexity of the subsequent regression analyses, it is worth simply laying bear first any differences on key study variables across two SES groups: a median split of lower and higher SES students in this sample. Table 4.7 displays the results of these t-tests. Using a family-wise-corrected p-value of 0.004, SES was not related to any of the key study variables.

Table 4.7
Results of t-Tests Contrasting Lower and Higher SES Students Over a Median Split

	Lower SES *M* (*SD*)	Higher SES *M* (*SD*)	*t* Value (*p*-value)
Symbol-Digit Modalities	42.57 (11.72)	45.69 (11.04)	1.42 (0.159)
Digit Span Backwards	4.48 (1.41)	5.04 (1.36)	2.08 (0.040)
Go-No-Go	7.54 (1.49)	7.80 (1.44)	0.93 (0.353)
Color-Shape Shifting	292.66 (369.02)	204.66 (480.08)	-1.03 (0.306)
Alphabetical-Categorical Fluency	10.28 (4.07)	12.61 (4.68)	2.76 (0.009)
DT Instances – Fluency	9.81 (3.78)	10.28 (4.28)	0.60 (0.552)
DT Instances – Originality	0.47 (0.24)	0.53 (0.20)	1.41 (0.162)
DT Uses – Fluency	6.48 (2.51)	7.39 (2.81)	1.77 (0.080)
DT Uses – Originality	0.70 (0.22)	0.73 (0.21)	0.63 (0.532)
Insight Problems	0.94 (1.14)	1.31 (1.15)	1.68 (0.095)
Remote Associates Test	2.81 (2.62)	4.15 (2.84)	2.54 (0.013)
World Scramble	9.22 (2.87)	9.72 (3.68)	0.79 (0.433)

Note. *M* (*SD*) = mean and standard deviation.
* $p < 0.004$ (family-wise error rate based on 12 statistical tests)

Does Student SES Predict the Creative Cognitive Skills?

In total, eight two-step regression models (with *p* values corrected for family-wise error rates) were estimated between the SES composite and each of the eight creative cognitive variables: Alphabetical-Categorical Fluency, Instances Fluency, Instances Originality, Uses Fluency, Uses Originality, Insight problems, RAT items, and Word Scramble items.

Table 4.8 shows the results of the model between SES and Alphabetical-Categorical Fluency. The initial model with only the covariates entered was not significant (*adj.* $R^2 = 0.06$; *p*-value = 0.022). Socioeconomic status was entered in the second step, yielding a significant overall model (*adj.* $R^2 = 0.14$; *p*-value = 0.001), as well as a significant increase in the total variance explained by the model (Δ *adj.* $R^2 = 0.08$; *p*-value = 0.002). Specifically, higher SES was associated with higher scores on the associative processing task ($\beta = 0.30$, *p*-value = 0.002).

Table 4.8
Two-Step Regression Results Relating SES to Associative Processing

		Model 1 (Covariates predicting AP)		Model 2 (Add SES)	
		Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
	Intercept	7.49		9.31	
	SES				0.30* (0.002)
Covariates					
	Multilingualism		0.24 (0.013)		0.19 (0.044)
	Processing speed		0.09 (0.390)		0.05 (0.650)
	Age		0.05 (0.651)		0.03 (0.789)
Adj. R^2			0.06 (0.022)		0.14* (0.001)
Δ Adj. R^2					0.08* (0.002)

Note. SES = socioeconomic status; AP = Associative Processing.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

The tables displaying the results of the models between SES and each of the four DT measures are displayed in full in Appendix C (Tables C.1 through C.4). None of the statistics estimated here were significant for any of the models. Specifically, neither multilingualism, nor age, nor processing speed explained any variance in the DT indicators. Furthermore, none of the SES coefficients were significant, none of the models including SES were significant, and none of the increases in adjusted R^2 were significant when SES was entered into the models.

Table 4.9 presents the model regressing Insight Problem scores on SES. The covariate-only model was significant overall (*adj.* $R^2 = 0.18$; p-value < 0.001), though none of the individual covariates were significant predictors. The model in which SES was entered was also significant (*adj.* $R^2 = 0.23$; p-value < 0.001), though none of the coefficients nor the change in variance explained were significant.

Table 4.9

Two-Step Regression Results Relating SES to Insight Problems

	Model 1 (Covariates predicting Insight)		Model 2 (Add SES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-2.12		-1.77	
SES				0.23 (0.011)
Covariates				
Multilingualism		0.21 (0.022)		0.17 (0.060)
Processing speed		0.20 (0.048)		0.16 (0.095)
Age		0.23 (0.020)		0.21 (0.026)
Adj. R^2		0.18* (<0.001)		0.23* (<0.001)
Δ Adj. R^2				0.05 (0.011)

Note. SES = socioeconomic status; Insight = Insight Problems.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

Table 4.10 presents the model regressing RAT item scores on SES. The initial model significantly explained about 19% of the variance in RAT scores (*adj.* $R^2 = 0.19$; *p*-value < 0.001), with being self-identified as multilingual associated with better scores (β = 0.27, *p*-value = 0.004). When SES was entered in the second step, the overall model was significant (*adj.* $R^2 = 0.25$; *p*-value < 0.001), the change in variance explained was significant (Δ *adj.* $R^2 = 0.06$; *p*-value = 0.002), and SES was the lone significant predictor of RAT scores (β = 0.28, *p*-value = 0.002), suggesting that higher SES was associated with higher scores.

Table 4.10
Two-Step Regression Results Relating SES to RAT Items

	Model 1 (Covariates predicting RAT)		Model 2 (Add SES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-2.49		-1.44	
SES				0.28* (0.002)
Covariates				
Multilingualism		0.27* (0.004)		0.22 (0.015)
Processing speed		0.24 (0.018)		0.19 (0.043)
Age		0.13 (0.192)		0.11 (0.246)
Adj. R^2		0.19* (<0.001)		0.25* (<0.001)
Δ Adj. R^2				0.06* (0.002)

Note. SES = socioeconomic status; RAT = Remote Associates Test items.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

The final model examining SES and creative cognitive skills focused on the Word Scramble items (Table 4.11). The initial covariate model was significant overall (*adj.* $R^2 = 0.16$; *p*-value < 0.001), but not of the coefficients were significant individually. In the second step, the overall model remained significant (*adj.* $R^2 = 0.15$; *p*-value < 0.001), though no coefficients were significant predictors.

Table 4.11
Two-Step Regression Results Relating SES to Word Scramble Scores

	Model 1 (Covariates predicting WS)		Model 2 (Add SES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	1.50		1.46	
SES				-0.01 (0.913)
Covariates				
Multilingualism		0.15 (0.098)		0.15 (0.101)
Processing speed		0.28 (0.007)		0.28 (0.007)
Age		0.15 (0.131)		0.15 (0.132)
Adj. R^2		0.16* (<0.001)		0.15* (<0.001)
Δ Adj. R^2				-0.01 (0.913)

Note. SES = socioeconomic status; WS = Word Scramble items.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

How are Specific Executive Functioning Skills Related to Each of the Creative Cognitive Skills?

Table 4.12 displays the results of the models regressing associative processing on the three executive skills. None of the statistics here estimated were significant at either step. Specifically, neither the covariates nor the executive skills significantly predicted associative processing task performance.

Table 4.12
Two-Step Regression Results Relating Executive Skills to Associative Processing

	Model 1 (Covariates predicting AP)		Model 2 (Add ES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	7.49		4.27	
Working Memory				0.25 (0.021)
Inhibitory Control				0.09 (0.332)
Shifting				-0.06 (0.543)
Covariates				
Multilingualism		0.24 (0.013)		0.23 (0.024)
Processing speed		0.09 (0.390)		0.01 (0.966)
Age		0.05 (0.651)		0.02 (0.886)
Adj. R^2		0.06 (0.022)		0.11 (0.011)
Δ Adj. R^2				0.05 (0.087)

Note. ES = executive skills; AP = associative processing.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Again, the models for DT are in Appendix C (Tables C.5 through C.8). None of the statistics estimated here were significant for any of the models. Specifically, neither multilingualism, nor age, nor processing speed explained any variance in the DT indicators. Furthermore, none of the executive skills coefficients were significant, none of the models including these skills were significant, and none of the increases in adjusted R^2 were significant when they entered into the models.

Table 4.13 shows the results of the model regressing Insight Problem performance on executive skills. The initial covariate model was significant overall (*adj.* $R^2 = 0.18$; p-value < 0.001), but not of the coefficients were significant individually. In the second step, the overall model remained significant (*adj.* $R^2 = 0.19$; p-value < 0.001), though neither the covariates nor the executive skills were significant predictors.

Table 4.13
Two-Step Regression Results Relating Executive Skills to Insight Problem Performance

	Model 1 (Covariates predicting Insight)		Model 2 (Add ES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-2.12		-2.35	
Working Memory				0.09 (0.378)
Inhibitory Control				0.10 (0.277)
Shifting				-0.13 (0.152)
Covariates				
Multilingualism		0.21 (0.022)		0.21 (0.028)
Processing speed		0.20 (0.048)		0.19 (0.095)
Age		0.23 (0.020)		0.17 (0.103)
Adj. R^2		0.18* (<0.001)		0.19* (<0.001)
Δ Adj. R^2				0.01 (0.301)

Note. ES = executive skills; Insight = Insight Problem items.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Table 4.14 shows the results of the model regressing RAT problem performance on executive skills. The initial model significantly explained about 19% of the variance in RAT scores (*adj.* $R^2 = 0.19$; *p*-value < 0.001), with being self-identified as multilingual associated with better scores (β = 0.27, *p*-value = 0.004). When executive skills were entered in the second step, the overall model was significant (*adj.* $R^2 = 0.25$; *p*-value < 0.001); however, the change in variance explained was not significant, nor were the any of the three executive skills significant predictors of RAT performance.

Table 4.14
Two-Step Regression Results Relating Executive Skills to RAT Problem Performance

	Model 1 (Covariates predicting RAT)		Model 2 (Add ES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-2.49		-4.32	
Working Memory				0.25 (0.011)
Inhibitory Control				-0.08 (0.359)
Shifting				-0.08 (0.384)
Covariates				
Multilingualism		0.27* (0.004)		0.22 (0.021)
Processing speed		0.24 (0.018)		0.12 (0.268)
Age		0.13 (0.192)		0.20 (0.039)
Adj. R^2		0.19* (<0.001)		0.25* (<0.001)
Δ Adj. R^2				0.06 (0.049)

Note. ES = executive skills; RAT = Remote Associates Test items.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Finally, Table 4.15 displays the results of the two-step model for executive skills and Word Scramble performance. The initial covariate model was significant overall (*adj.* $R^2 = 0.16$; *p*-value < 0.001), but not of the coefficients were significant individually. In the second step, the overall model remained significant (*adj.* $R^2 = 0.18$; *p*-value < 0.001), though neither the covariates nor the executive skills were significant predictors.

Table 4.15
Two-Step Regression Results Relating Executive Skills to Word Scramble Performance

	Model 1 (Covariates predicting WS)		Model 2 (Add ES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	1.50		-0.15	
Working Memory				0.10 (0.320)
Inhibitory Control				0.03 (0.761)
Shifting				-0.14 (0.141)
Covariates				
Multilingualism		0.15 (0.098)		0.12 (0.211)
Processing speed		0.28 (0.007)		0.24 (0.035)
Age		0.15 (0.131)		0.18 (0.084)
Adj. R^2		0.16* (<0.001)		0.18* (<0.001)
Δ Adj. R^2				0.02 (0.381)

Note. ES = executive skills; WS = Word Scramble items.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Are SES-Creative Cognitive Relations Mediated by or in Interaction With Executive Skills?

To review, this final research question was concerned with two viewpoints. The first was the degree to which any relationships found between SES and creative cognitive skills (addressed by the first research question) might be explained by any of the executive skills. The preceding analyses found that SES significantly predicted associative processing and RAT performance. The next step was to determine if any of the executive skills mediate part of these two SES-creative cognitive skills relationships by examining two separate stepwise models aimed at uncovering evidence of mediation (with *p* values corrected for family-wise error rates).

Table 4.16 shows the results of the mediational model predicting associative processing. Model 1 (*adj.* R^2 = 0.14; *p*-value = 0.001) restates the significant prediction of associative processing by SES (β = 0.30, *p*-value = 0.002). When executive skills were added to the model, the overall model was still significant in predicting associative processing (*adj.* R^2 = 0.15; *p*-value = 0.002). However, neither SES nor executive skills were significant predictors in the model, and the change in variance explained was not a significant improvement over the more parsimonious model.

Table 4.16

Two-Step Regression Examining Mediation of SES-Associative Processing by Executive Skills

	Model 1 (No ES)		Model 2 (Add ES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	9.31		6.37	
SES		0.30* (0.002)		0.25 (0.014)
Possible Mediators				
Working Memory				0.19 (0.070)
Inhibitory Control				0.07 (0.432)
Shifting				-0.05 (0.625)
Covariates				
Multilingualism		0.19 (0.044)		0.20 (0.051)
Processing speed		0.05 (0.650)		-0.02 (0.892)
Age		0.03 (0.789)		0.01 (0.937)
Adj. R^2		0.14* (0.001)		0.15* (0.002)
Δ Adj. R^2				0.01 (0.254)

Note. SES = socioeconomic status; ES = executive skills.
* $p < .004$ (family-wise error rate based on 14 statistical tests)

Table 4.17 shows the results of the mediational model predicting RAT performance. Model 1 (*adj.* $R^2 = 0.25$; *p*-value < 0.001) restates the significant prediction of RAT scores by SES (β = 0.28, *p*-value = 0.002). When executive skills were added to the model, the overall model was still significant in predicting RAT scores (*adj.* $R^2 = 0.30$; *p*-value < 0.001). However, neither SES nor executive skills were significant predictors in the model, and the change in variance explained was not a significant improvement over the more parsimonious model.

Table 4.17
Two-Step Regression Examining Mediation of SES-RAT Performance by Executive Skills

	Model 1 (No ES)		Model 2 (Add ES)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-1.44		-2.97	
SES		0.28* (0.002)		0.26 (0.006)
Possible Mediators				
Working Memory				0.19 (0.043)
Inhibitory Control				-0.10 (0.237)
Shifting				-0.07 (0.455)
Covariates				
Multilingualism		0.22 (0.015)		0.18 (0.048)
Processing speed		0.19 (0.043)		0.10 (0.346)
Age		0.11 (0.246)		0.20 (0.039)
Adj. R^2		0.25* (<0.001)		0.30* (<0.001)
Δ Adj. R^2				0.05 (0.115)

Note. SES = socioeconomic status; ES = executive skills; RAT = Remote Associates Test items.
* $p < .004$ (family-wise error rate based on 14 statistical tests)

The second perspective on this final question concerned profiles of cognitive skills, which might be illuminated by interactions between participant SES background and their executive skills. Table 4.18 displays the results of the first of these models (all with *p* values corrected for family-wise error rates) with associative processing regressed on the addition of interaction terms (Model 2). The first model with first-order SES and executive skills estimations predicted significant variance in associative processing scores (*adj.* R^2 = 0.15; *p*-value = 0.002); however, no individual coefficients were significant predictors. When the interaction terms were entered in the second model, none of the statistics here examined were significant: individual regressors, adjusted R^2, or change in adjusted R^2.

Table 4.18

Two-Step Regression Examining SES-Executive Skills Interactions Predicting Associative Processing

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	6.37		7.73	
SES		0.25 (0.014)		-0.09 (0.894)
Working Memory		0.19 (0.070)		0.19 (0.075)
Inhibitory Control		0.07 (0.432)		0.08 (0.427)
Shifting		-0.05 (0.625)		-0.03 (0.760)
SES x Working Memory				0.29 (0.453)
SES x Inhibitory Control				-0.04 (0.938)
SES x Shifting				0.16 (0.230)
Covariates				
Multilingualism		0.20 (0.051)		0.19 (0.062)
Processing speed		-0.02 (0.892)		-0.01 (0.920)
Age		0.01 (0.937)		-0.03 (0.776)
Adj. R^2		0.15* (0.002)		0.14 (0.007)
Δ Adj. R^2				-0.01 (0.582)

Note. SES = socioeconomic status.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

Similar to the trends observed when addressing the above research questions, none of the models regressing any of the divergent thinking variables on first order, interaction, or covariate variables were significant. The full results of these analyses are available in Appendix C (Tables C.9 through C.12).

Table 4.19 displays the results of the models predicting Insight Problem performance. The first model with first-order SES and executive skills estimations predicted significant variance in Insight Problem scores (*adj.* $R^2 = 0.21$; *p*-value < 0.001); however, no individual coefficients were significant predictors. When the interaction terms were entered in the second model, the overall model still significantly predicted variance in scores (*adj.* $R^2 = 0.20$; *p*-value = 0.001), though, none of the individual coefficients were significant predictors and the change in variance explained was not a significant improvement over the more parsimonious model.

Table 4.19
Two-Step Regression Examining SES-Executive Skills Interactions Predicting Insight Problem Performance

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-1.97		-1.76	
SES		0.18 (0.065)		-0.31 (0.651)
Working Memory		0.05 (0.625)		0.07 (0.516)
Inhibitory Control		0.09 (0.346)		0.08 (0.356)
Shifting		-0.13 (0.177)		-0.13 (0.184)
SES x Working Memory				0.51 (0.171)
SES x Inhibitory Control				-0.03 (0.961)
SES x Shifting				0.04 (0.771)
Covariates				
Multilingualism		0.19 (0.051)		0.17 (0.094)
Processing speed		0.17 (0.120)		0.18 (0.113)
Age		0.16 (0.109)		0.13 (0.217)
Adj. R^2		0.21* (<0.001)		0.20* (0.001)
Δ Adj. R^2				-0.01 (0.576)

Note. SES = socioeconomic status.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

Table 4.20 displays the results of the models predicting RAT performance. The first model with first-order SES and executive skills estimations predicted significant variance in RAT scores (*adj.* $R^2 = 0.30$; *p*-value < 0.001); however, no individual coefficients were significant predictors. When the interaction terms were entered in the second model, the overall model still significantly predicted variance in scores (*adj.* $R^2 = 0.31$; *p*-value < 0.001), though, none of the individual coefficients were significant predictors and the change in variance explained was not a significant improvement over the more parsimonious model.

Table 4.20
Two-Step Regression Examining SES-Executive Skills Interactions Predicting RAT Performance

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-2.97		-3.00	
SES		0.26 (0.006)		-0.43 (0.498)
Working Memory		0.19 (0.043)		0.22 (0.022)
Inhibitory Control		-0.10 (0.237)		-0.10 (0.227)
Shifting		-0.07 (0.455)		-0.09 (0.330)
SES x Working Memory				0.63 (0.070)
SES x Inhibitory Control				0.16 (0.748)
SES x Shifting				-0.11 (0.340)
Covariates				
Multilingualism		0.18 (0.048)		0.15 (0.109)
Processing speed		0.10 (0.346)		0.10 (0.317)
Age		0.20 (0.039)		0.18 (0.064)
Adj. R^2		0.30* (<0.001)		0.31* (<0.001)
Δ Adj. R^2				0.01 (0.224)

Note. SES = socioeconomic status; RAT = Remote Associates Test items.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

Finally, Table 4.21 displays the results of the models predicting Word Scramble performance. Similar to the findings for DT, none of the key statistics here interpreted were significant, suggesting no predictive or mediational findings.

Table 4.21

Two-Step Regression Examining SES-Executive Skills Interactions Predicting Scramble Performance

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β (*p*-value)	Coefficient	β (*p*-value)
Intercept	-0.12		-0.78	
SES		0.00 (0.964)		-0.10 (0.890)
Working Memory		0.10 (0.338)		0.12 (0.255)
Inhibitory Control		0.03 (0.766)		0.02 (0.796)
Shifting		-0.14 (0.144)		-0.16 (0.091)
SES x Working Memory				0.22 (0.564)
SES x Inhibitory Control				0.01 (0.978)
SES x Shifting				-0.19 (0.160)
Covariates				
Multilingualism		0.12 (0.221)		0.10 (0.342)
Processing speed		0.24 (0.037)		0.24 (0.038)
Age		0.18 (0.086)		0.19 (0.072)
Adj. R^2		0.17 (0.001)		0.17 (0.003)
Δ Adj. R^2				0.00 (0.491)

Note. SES = socioeconomic status.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

Discussion and Conclusions

Recognizing a contemporary emphasis on creativity in practice and research, we sought to analyze it in a way that illuminates how it might differ according to student socioeconomic circumstances. Rather than arriving at a clear, simple answer, we expected this analysis to be complex, involving multiple cognitive skills underlying creative behaviors to exhibit different profiles across the socioeconomic spectrum. We expected to see relationships – positive or negative – between SES, executive skills, and creative cognitive skills.

Our results show that an educational, non-deficit, profile perspective of the way these cognitive skills relate to student SES is a useful one. Indeed, we did not see any simple evidence that, for example, students from higher SES backgrounds are more creative; instead, what we found were different cognitive landscapes for students from different backgrounds. Regardless of socioeconomic status, students performed similarly on many of the cognitive skills, including executive shifting, inhibitory control, and divergent thinking, with mixed results for measures of insight. All of these important cognitive skills thought to contribute in some way to creative behaviors are therefore available in the cognitive toolkits of students from all socioeconomic circumstances. Among the skills we examined, students from families with more prestigious occupations, higher household incomes, and higher education attainment did exhibit some strengths upon which practitioners might capitalize: associative processing, as well as insight, again, with mixed findings, and possibly working memory. In sum, SES might not be conceived of as the blanket, deficit predictor of creative cognitive and executive skills as it has been reported for other important educational skills; like past social neurocognitive findings, SES is not globally related to cognition, but rather seems to differentially (un)related to different creative cognitive skills.

Students from a Variety of Socioeconomic Environments Access Certain Cognitive Skills Similarly

While other have found associations between SES and some of the cognitive skills explored here, there are possible reasons why those associations might be products of specific research circumstances and not characteristic of a student's SES designation writ large. In the case of executive shifting, our measure was modeled as closely as possible on that used by Mittal and colleagues (2015) where they found an advantage for adults of lower SES in experimentally-induced uncertain conditions. We neither had an adult sample nor had experimentally-induced uncertain conditions. While that study provided enough justification to explore this relationship in a younger population, this could explain why we did not see an advantage on this task for our lower SES students (though, it is worth repeating that we also did not find any disadvantage). Indeed, early in development, our young students might be well-equipped in this regard.

That we found no associations between SES and either inhibitory control or shifting should be emphasized in support of our non-deficit, neurocognitive profile framework, standing in contrast to oft-published statistically significant findings. We have reviewed the evidence for the importance of executive functions in childhood development and educational success. That SES might not be as strongly related to some of these (or as many of these) executive functions as we thought is an important contribution to our understanding of SES disparities in education. However, these findings should be viewed cautiously until replicated, particularly given the contradictory findings in other studies. One possible reason for this disparity might be in the composition of our sample: though in different ways, all of the participants were somehow identified for talent development potential. It is worth examining further whether or not possessing the sorts of skills – cognitive or otherwise – that predispose a student for talent identification acts as a sort of indicator of cognitive adaptation, regardless of socioeconomic circumstances.

Our finding that a student's socioeconomic context does not predict her divergent thinking abilities stands in contrast to the research reviewed above showing connections between the executive skills we examined and both SES and divergent thinking, as well as prior findings that SES may be related to DT (Dai et al., 2012). This could be due to the essence of socioeconomic differences and their relation to academic outcomes. Whereas culture and household background may play a larger role in the sort of academic language skills requisite for success on, for example, verbal measures of associative processing, the role for divergent thinking may be minimal – indeed, even an advantage. Regardless of their socioeconomic background, these students could generate the same number of responses, even if the content of those responses differed substantially; they could generate responses that made sense within the socioeconomic contexts to which they have adapted. Perhaps *precisely because of their divergent socioeconomic backgrounds* we saw similar levels of originality across the SES spectrum. In other words, if the SES differences in this sample were associated with different experiences in recognizing instances of a certain shape or uses for a brick, we should expect to see responses considered original from students of different types of households, with all having a similar opportunity to demonstrate fluency. Original, creative ideas are likely to come from students who have different experiences as they develop – ideas that can benefit their education and society.

There are clear implications for a socioeconomically-unbiased creative cognitive measure. Insofar as generating divergent solutions to problems is important in any educational domain, assessing divergent thinking (and its development) is an important responsibility in education. Having measures capable of assessing this development *apart from a student's socioeconomic background* would be an improvement over many other academic measures that illuminate differences. Further, educators might capitalize upon divergent thinking skills as a resource readily available to students from diverse households. Given Kim's (2008) meta-analytical findings of both a moderate correlation between divergent thinking and creative achievement, as well as a meaningful dissociation between creative cognitive abilities and conventional academic skills and intelligence, assessing divergent thinking may be an important tool for those educating students across the talent development spectrum to have a fuller portrait of each learner's abilities, as well as any needs for specific interventions (Delis et al., 2007).

If the identification and development of exceptional divergent thinking is an important component of any talent development program – focused on creativity or otherwise, an SES-unbiased measure is especially important for ensuring equitable access and outcomes. Kaufman, Plucker, and Russell (2012) noted that divergent thinking measures are the most widely used indicators of creative potential and are also often used for talent development identification purposes. Many conventional, standardized assessments for talent development opportunities, such as those of intelligence (e.g., those assessing IQ; Torrance, 1971), are thought to be biased indicators of talent, favoring non-minority, more affluent students who have greater access to educational opportunities (e.g., Jencks & Phillips, 1998; Steele, 1997). So, perhaps the use of certain creative cognitive measures, like those assessing divergent thinking, are less curriculum-, culturally-, or socially-dependent than others, and thus may serve to more equitably admit students from historically underrepresented groups to talent development programs seeking to foster creativity. It is well established that lower-SES and minority students are historically underrepresented in talent development programs, and many researchers have called for greater inclusion (e.g., Olszewski-Kubilius & Clarenbach, 2012; Plucker, Burroughs, & Song, 2010). These findings suggest a path towards greater inclusion. To expand upon these findings, future research could also incorporate students not participating in a talent development opportunity to see if the present similarities in divergent thinking performance are replicated and significantly different from students not participating. If born out, this would further justify an imperative for using divergent thinking measures to equitably identify and develop creative talent.

Importantly, though much of the prior social cognitive neuroscience work has painted a deficit picture of the cognitive skills of lower SES students, the shifting, inhibitory control, and divergent thinking – and possibly other insight-related – findings here stand in contrast. If replicated, these results suggest that educational equity regarding SES is not as simple as "correcting the deficits of lower SES students in order to bring them up to the levels of their more advantaged peers;" there may be some skills – such as divergent thinking – on which students across the SES spectrum can equally capitalize upon when learning and developing. Indeed, if the results of Mittal and colleagues (2015) can be extended to school-aged children, in certain contexts, lower SES students might actually have advantages that higher SES students would need to address to create cognitive parity. This type of work which helps to illuminate the level of learner profiling we might eventually attain in the realms of research and practice may ultimately lead to more nuanced guidance for practice and interventions, pinpointed to capitalize on the cognitive strengths of a student in order to further develop their skills with development potential.

Creative Cognitive Strengths for Students from Higher Socioeconomic Backgrounds

To consider the significant positive associations between SES and both associative processing and insight (particularly as evidenced by RAT performance), we have to consider non-executive lines of explanation, as there was little evidence of executive mediation. It is important to note that the measures of associative processing and insight were all verbal as opposed to spatial. While the divergent thinking tasks – on which there were no differences across the SES spectrum – required the student to read a single-sentence prompt and generate verbal answers, the other creative cognitive tasks arguably required more extensive knowledge of vocabulary and reading comprehension. For example, the associative processing task required knowledge of a wide array of vocabulary in the domains of animals or fruits and vegetables. Farah and colleagues (2006) provide just one recent neurocognitive example in a long lineage of sociological language-equity research of finding a relationship between SES and language processing, including a measure of vocabulary in particular. Future research should examine the extent to which SES plays a role in performance on *spatial*, or other nonverbal, measures of insight and associative processing, as well as SES differences on particular types of insight measures, given the null findings for our word problems and scrambles.

One of the implications of this finding is that we can add verbal associative processing – and possibly verbal insight – to the long list of education-related outcomes that have displayed similar advantages for higher SES students. This is a notable addition to our research base given the findings from our review of prior research in this area marked by little to no relationships with SES. Given that creativity is being emphasized more in contemporary education curricula and reforms, and given that these creative cognitive skills may predict creative behaviors and accomplishments, it is important to consider additional policy and practice interventions in order to more equitably distribute opportunities for their development.

Golnabi (2016) provides one analysis of how the cognitive processes involved in insight problem solving (such as those thought to substantially underlie RAT performance) are similar to – and perhaps closely intertwined with – performance solving math problems. If such relationships are found to be substantially true, the present findings could have ramifications for SES differences when solving such math problems – as well as implications for how to intervene. In a similar vein, Lv (2015) provides an analysis of insight problem solving (albeit not RAT problem solving) broken into two stages – an initial phase for solution searching, followed by a phase in which the problem is reconceived to arrive at a solution. Each phase in that study was found to correspond distinctly with working memory or inhibition, respectively. That sort of analysis and future work can provide the foundation for interventions aimed at improving students' verbal insight problem solving abilities.

Unlike next research steps with divergent thinking, where extensive work over decades has examined the psychometric properties of various measures, there is still much more work to be done with associative processing and insight problem solving in this domain. The research community should establish a few reliable, valid measures so that findings such as these and others can be replicated or qualified across different samples and contexts. Given the empirical history of RAT research, this measure may be a particularly suitable candidate for insight problem solving. Further, these findings suggest the importance of measuring and controlling for SES when examining verbal associative processing or RAT performance. Knowing about inequities that can be intervened upon allows for any number of actions in education, including broadly measuring these creative cognitive skills in students or adding such skills as part of accountability systems to ensure that they are being developed equitably.

Limited Overall Support for Executive Creative Cognition

Our correlations results suggested that working memory – more so than inhibitory control or shifting – was the important executive skill to consider for both SES and creative cognitive skills – not executive functioning writ large. That is, perhaps SES has a more granular, nuanced relationship with specific executive functioning skills, or even with specific skills in different developmental and environmental contexts. To reiterate, there was no evidence of roles for either shifting or inhibition in any of the creative cognitive skills, similar to the findings of Lee and Therriault (2013), who noted only a working memory underpinning. Further, we found no evidence of executive mediation between SES and creative cognitive skills. However, we do replicate what is now extensive evidence of a small to moderate relationship between SES and working memory in primary-aged students, in educational settings throughout the United States. Indeed, recent findings by Finn and colleagues (2017) in adolescents show the intertwined nature of working memory performance, the neural underpinnings of working memory, family income, and student achievement in mathematics.

This is a substantial departure from prior findings which have implicated working memory, inhibition, and shifting in certain creative cognitive skills. One reason for this departure may pertain to the developmental level of our sample. Prior findings are largely confined to college-aged samples (e.g., Gilhooly, Fioratou, Anthony, & Wynn, 2007; Nusbaum & Silvia, 2011), and we know that executive, prefrontal-dependent skills tend to follow a protracted developmental pathway. There are also differences in the tasks used to measure these constructs across studies (e.g., Mittenecker Pointing Test; Rominger et al., 2018, p. 260) – partly as a function of developmental differences: task difficulty needed to be taken into account in the present study given the ages of the participants. Also, when studying the neural underpinnings of working memory across development, Bathelt, Gathercole, Johnson, and Astle (2018) found that, though the cognitive representation of working memory did not change during childhood development, the neural underpinnings did; a diffuse network in early childhood became increasingly narrow and specialized in later childhood. It is possible that the way in which this working memory network interacts with performance on creative cognitive tasks may thus change throughout childhood and into adulthood, allowing for executive explanations of creative performance in older samples. This underscores the importance of studying these relationships across childhood development.

One possibility for the null findings between working memory and our measures of insight is that the particular demands of our insight tasks may not have favored working memory support. In a commentary and response to prior findings, DeCaro, Van Stockum Jr., and Wieth (2017) proposed that working memory may alternately benefit or detract from performance on insight problems depending upon the type of insight problem and the particular stage of the problem-solving process. In some of their original experiments (DeCaro, Van Stockum Jr., & Wieth, 2016), they similarly suggested that working memory may alternately hinder or benefit different parts of the insight problem solving process, which might effectively nullify any correlational findings when looking at the process as a whole. A more fruitful way of examining this might therefore be to analyze the insight process in small components, alongside working memory.

Therefore, one example of how this area of research might progress and the aim to which it might progress is the *Executive Abilities: Measures and Instruments for Neurobehavioral Evaluation and Research (EXAMINER)* project, as explained by Kramer and colleagues (2014). They noted both inconsistencies in how executive functioning was being operationalized and measured, as well as the somewhat vague broadness of the construct, necessitating more granularity for further research and clinical work. While the field of creativity research is far from that of executive functioning in hoping to undertake a project like this in the short-term, this sort of work serves as a blueprint and long-term goal for what is currently needed: the compilation of various creative cognitive skills into a battery that is exhaustive in measuring the underpinnings of creative behavior and also conceptually instructive in explaining the cognitive landscape of creativity. Once such a conceptualization and battery of creative cognitive measures is agreed upon in the field, the next step would be to examine carefully the associations between an executive functioning battery such as the EXAMINER and the resulting creative cognitive battery in order to shed more light upon the relations between these two constructs.

In the short-term, more work like that done by Nusbaum and Silvia (2011) and in the present study is needed to catalogue what we know individually about these collections of executive and creative cognitive skills (variously operationalized, across various developmental contexts), the accumulation of which will begin to provide a clearer picture of any overlap in these executive and creative cognitive landscapes. For example, Kleibeuker, De Dreu, and Crone (2016) provided an overview of the development of distinct creative cognitive skills during adolescence and beyond; similar work is needed beginning earlier in childhood. Further, researchers publishing work in this area need to find ways to share both null and significant findings for specific, disaggregated executive functioning and creative cognitive skills. It remains unclear why some researchers find significant evidence and others null, and a fuller picture of the research results may help illuminate this puzzle. Meta-analyses may prove particularly useful for meeting this need.

As mentioned above, Lv (2015) provides one useful illustration of the granularity to which we might strive in mapping this cognitive area. Given the present correlational findings between working memory and creative cognitive skills, there is a foundation for similar microscopic work as an extension of these results. For example, Baddeley (2012) described a widely-accepted four-component model of working memory, including central executive, visuo-spatial sketch-pad, phonological loop, and episodic buffer components. Just as we analyzed components of executive functioning, so too might future studies examine the components of working memory in relation to creative cognitive skills and phases of their processes. Indeed, Swanson and Fung (2016) provide an example of doing something similar with working memory and solving math word problems with implications for exploring ways to improve mathematical abilities at a newly granular level.

While the implications of these findings for policy and practice are somewhat tenuous, they add controversy to the research examining the neurocognitive underpinnings of creativity. For example, Nusbaum and Silvia (2011) made the argument that executive functioning is central to divergent thinking. Here, in a younger, talent development sample, we failed to replicate that finding, suggesting the need for future research to reconcile these divergent findings. At the very least, an executive explanation of divergent thinking skills needs to be examined for its reliability; however, it may be time to either broaden (beyond executive functioning) or narrow (to a specific executive skill, such as working memory and its components) the search for more substantial cognitive underpinnings of this central skill in the creativity literature. At present, these findings suggest that these three executive skills will not provide substantial inroads into profiling learners' creativity-related skills and thus might also not be the most fruitful course for seeking to develop these creative cognitive skills through personalized educational interventions. This presents opportunities for both the cognitive and nascent neural investigations of creativity to explore alternatives. The largely null findings for interrelations between and mediation of SES and creative cognitive skills by executive skills is that the proposed bridge between the two as-of-yet disparate research bases of social cognitive neuroscience and the neurocognitive study of creativity is not built on any sort of substantial executive functioning foundation.

Limitations

It is important to clearly restate what this study did and did not accomplish. The aim of this study was to investigate the relationships between student SES, executive functioning skills, and creative cognitive abilities. So, as has been emphasized throughout, this does not provide a comprehensive investigation of creativity, broadly conceived. There are many theoretical lenses and a variety of different measures in the field of creativity research; this research was specifically conducted within a neurocognitive framework, examining three particular verbal cognitive abilities predictive of creative behavior. Thus, the conclusions reached here about relationships between student SES, verbal associative processing, and verbal RAT performance do not generalize to all of that which creativity encompasses, such as personality or cultural context. Conclusions can only be drawn about individual cognition and individual family background. However, because contextual influences are important to recognize, future studies seeking to extend upon these findings might consider also including, for example, measures of the average SES level at the student's school or census tract in order to determine if this adds any additional explanatory power to creative cognitive findings.

It is worth emphasizing further that not only do these findings inform one theoretical lens regarding creativity, they also are limited in the verbal nature of the measures. That is, not only are any conclusions reached here linked only with verbal measures of creative cognitive skills, but the conclusions need to also be interpreted prudently given the substantial evidence base (some of which was reviewed above) of moderate to strong relationships between SES and various measures of language skills (e.g., comprehension, decoding, vocabulary recognition). Given these known connections, future research should consider less-verbally-dependent creative cognitive measures or even spatial measures, such as the common figural counterparts to the DT tasks used here. Indeed, the creative cognition approach described by Finke, Ward, and Smith (1992) explicitly focuses on the manipulation of mental forms in much the same way common measures of spatial abilities require a person to imagine manipulating a two-dimensional representation of a three-dimensional shape in order to arrive at other perspective and solutions. It remains to be seen if the associations we found between SES and both associative processing and insight (as measured by the RAT items) can be replicated on more spatially-reliant measures of these skills.

This was a cross-sectional snapshot of students' cognitive skills and households at one point in their developmental trajectories. Thus, this research design limits the ability to draw causal inferences. Though causal work in the neurocognitive animal literature was presented as a theoretical backdrop for some of the SES-executive functioning connections, it is not possible to conclude from these results that SES caused higher performance task performance.

The results of this study will need to be replicated in other contexts, particularly given the nascent state of neurocognitive investigations of creativity. External validity is somewhat limited (as conceived in Shadish, Cook, & Campbell, 2002) in that students are being sampled voluntarily and purposively from relatively distinct settings around Baltimore and within a narrow age range. Further, the range of academic abilities in this sample may be limited in variation in that we only recruited from talent development settings. It is not clear to what population these results will generalize. However, given that this study is an initial exploration of the relationships between these constructs, external validity is not an immediate concern, and in fact is quite typical of many basic neurological and cognitive research studies. It might be imagined, though, that future large-scale educational datasets could begin incorporating more specific cognitive measures pertaining to creativity, as they already have for executive functioning (e.g., see description of ECLS-K:2011 in Little, 2017) and socioeconomic status. These would be in addition to the broader academic achievement and behavioral measures traditionally included and would thus allow for a much broader examination of the findings noted here and elsewhere in this area of research, with a sample more clearly generalizable, and with the ability to tie these measures to conventional academic measures.

There is also evidence that the testing environment is related to performance on various creativity measures, including divergent thinking in particular (Fishkin & Johnson, 1998; Plucker & Makel, 2010).

It was not practical in this study to recruit all students to the exact same room or setting since students were distributed geographically and temporally. In order to maximize our sample size (and thus statistical power) we sacrificed control of the immediate testing context. Though we made every effort to ensure that the testing conditions were as similar as possible (e.g., all students were tested individually with a researcher, with the same data collection methods, in rooms of roughly the same sizes), we caution that not all possible conditions could be controlled. For example, when examining responses to the divergent thinking tasks, it was not uncommon to observe that some of the initial responses given by students coincided with items in the room where they were completing the task (e.g., a globe for round items, or classroom books for square items). This concern is somewhat mitigated because multiple students were often tested in the same room, so such idiosyncratic responses primed by the immediate environment usually did not meet the threshold for being marked original since multiple students used this same strategy within the same setting.

Finally, there are limitations (as well as benefits) to the sort of rule-based, replicable procedure we used for scoring participant responses on the DT tasks. As already noted, one of the main benefits was efficiency; time-consuming DT scoring procedures have been noted as a barrier to including DT tasks in large-sample studies and has motivated others to seek less time-consuming alternatives (Silvia, Martin, & Nusbaum, 2009). Another is that if any other researcher wished to replicate these results with this dataset, the above procedures should prove sufficiently clear to reproduce the DT fluency and originality scores. A limitation of this method is that, though the above procedures could be *applied* objectively, their *creation* is obviously not objective. Whereas we believed words such as “a” or “the” to be inconsequential in distinguishing original responses, others may disagree. Others may suggest that our decision not to distinguish between plural and singular versions of the same response might not go far enough. Ultimately, we believe the advantages associated with this objective scoring method outweigh any perceived limitations.

Conclusion

The results of this research present evidence for a relationship between student socioeconomic status and two common constructs associated with creative cognition: associative processing and insight, as measured by RAT performance. More noteworthy, however, is what we did not find. There is no substantial evidence in this sample that SES is related to four common measures of divergent thinking performance, two common indicators of executive functioning (shifting and inhibitory control), or two measures of insight. Further, we were unable to replicate prior findings of any substantial executive functioning underpinnings of creative cognitive abilities. Perhaps it is best to progress to a view executive functioning and creative cognitive skills as constructs: labels for a collection of underlying skills which should be operationalized and analyzed separately to advance the science and illuminate complex relationships with a student's social circumstances. And, altogether, these results demonstrate the usefulness of considering cognitive profiles of students from different socioeconomic context – a non-deficit, strength-based approach to learning. If replicated, these findings have potentially important implications for discussions about the policy and practice of educational equity regarding creativity, as well as creative cognitive theory and basic research.

Appendix A

Program Type Associations with Executive and Creative Cognitive Skills

Because of the above-mentioned relationships between student race and ethnicity, Program Type, and SES in this sample, it may be reasonable to ask whether or not the core analyses might look different if examined by Program Type, rather than SES. Given Program Type's categorical nature, we estimated ANOVA models at alpha levels of 0.05 to evaluate associations between a student's program participation and the cognitive abilities being presently examined.

Executive functioning skills. Three one-way ANOVA models were created, for working memory, inhibitory control, and shifting, by program type (i.e., enrichment, summer, or lab). Only the model for working memory was significant ($F = 7.20$). Pairwise comparison of means revealed that the summer students performed significantly better than both the lab and enrichment students.

Creative cognitive skills. Eight one-way ANOVA models were created, for Alphabetical-Categorical fluency, DT Instances fluency, DT Instances originality, DT Unusual Uses fluency, DT Unusual Uses originality, Insight Problem scores, RAT scores, and Word Scramble scores. Five models were significant: Alphabetical-Categorical fluency ($F = 6.83$), DT Instances originality ($F = 3.16$), Insight Problems ($F = 14.54$), RAT ($F = 12.90$), and Word Scramble scores ($F = 4.35$). Subsequent post-hoc Tukey comparisons of group means revealed that summer students outperformed their enrichment peers in each model, and lab students also outperformed their enrichment peers on Insight Problem items.

We found that SES was related with associative processing, one measure of DT, and insight. These findings are basically replicated here and the likely explanation is the SES compositions of the different program types. The only difference we noted was that SES was related with DT Instances fluency whereas Program Type is here associated with DT Instances originality. It is worth mentioning that though our measure of originality is intended to control as much as possible the contribution of fluency, it is still only moderately successful in doing so, and so a relationship with either of these similar variables is not surprising.

Appendix B

Given that, of the variables where missing values were addressed, SES both plays a critical role in the analyses *and* represented a relatively large number of removed students, we conducted additional analyses to see if these 14 students, removed from the dataset, were different in important ways from the remaining students with at least one SES indicator present (i.e., those included in our results). Because both Program Type and race and ethnicity are closely related to SES in the overall sample, these two variables were examined first.

Table B.1
Comparison of Race and Ethnicity and Program Type Frequencies

	% of Analytical Sample	% of Removed Sample	Two-Sample Proportions Test
Program Type			
Enrichment	54.63%	68.75%	$z = 1.06$ ($p = 0.29$)
Lab	12.04%	12.50%	$z = 0.05$ ($p = 0.96$)
Summer	33.33%	18.75%	$z = -1.17$ ($p = 0.24$)
Race and Ethnicity			
Asian	14.81%	12.50%	$z = -0.96$ ($p = 0.34$)
Black or African American	37.04%	43.75%	$z = 1.17$ ($p = 0.24$)
White	29.63%	25.00%	$z = -0.59$ ($p = 0.56$)

The above table demonstrates, that for the Program Types and races and ethnicities known to be related to SES in this sample, there were no significant differences in the proportions of those categories between the groups excluded from and included in the subsequent analyses. In fact, an examination of correlation coefficients between whether or not the student was included in the analysis and all other key study variables – using a liberal p-value of 0.05 – revealed only one significant correlation with age (r = 0.19, p-value = 0.035; there is a small tendency for those students included to be older than those not included).

Appendix C

Below are complete tables for the regression results not shared in the *Results* chapter due to null or similar results.

Does Student SES Predict the Creative Cognitive Skills?

Table C.1
Two-Step Regression Results Relating SES to DT (Instances Fluency)

		Model 1 (Covariates predicting DT)		Model 2 (Add SES)	
		Coefficient	β	Coefficient	β
	Intercept	5.69		5.85	
	SES				0.03 (0.766)
Covariates					
	Multilingualism		0.12 (0.210)		0.12 (0.239)
	Processing speed		0.12 (0.271)		0.11 (0.295)
	Age		0.07 (0.538)		0.06 (0.553)
Adj. R^2			0.02 (0.146)		0.01 (0.244)
Δ Adj. R^2					-0.01 (0.766)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

Table C.2
Two-Step Regression Results Relating SES to DT (Instances Originality)

		Model 1 (Covariates predicting DT)		Model 2 (Add SES)	
		Coefficient	β	Coefficient	β
	Intercept	0.25		0.29	
	SES				0.15 (0.125)
Covariates					
	Multilingualism		0.04 (0.670)		0.02 (0.874)
	Processing speed		0.20 (0.067)		0.18 (0.104)
	Age		0.04 (0.706)		0.03 (0.778)
Adj. R^2			0.03 (0.120)		0.04 (0.085)
Δ Adj. R^2					0.01 (0.125)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

Table C.3
Two-Step Regression Results Relating SES to DT (Uses Fluency)

		Model 1 (Covariates predicting DT)		Model 2 (Add SES)	
		Coefficient	β	Coefficient	β
	Intercept	5.22		5.97	
	SES				0.21 (0.038)
Covariates					
	Multilingualism		0.03 (0.728)		0.00 (0.992)
	Processing speed		0.15 (0.174)		0.12 (0.277)
	Age		0.01 (0.962)		-0.01 (0.933)
Adj. R^2			0.00 (0.418)		0.03 (0.126)
Δ Adj. R^2					0.03 (0.038)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

Table C.4

Two-Step Regression Results Relating SES to DT (Uses Originality)

		Model 1 (Covariates predicting DT)		Model 2 (Add SES)	
		Coefficient	β	Coefficient	β
	Intercept	0.95		0.95	
	SES				0.02 (0.849)
Covariates					
	Multilingualism		0.00 (0.997)		0.00 (0.971)
	Processing speed		-0.14 (0.193)		-0.15 (0.190)
	Age		-0.06 (0.559)		-0.06 (0.553)
Adj. R^2			0.00 (0.339)		0.00 (0.496)
Δ Adj. R^2					0.00 (0.849)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .005$ (family-wise error rate based on 10 statistical tests)

How are Specific Executive Functioning Skills Related to Each of the Creative Cognitive Skills?

Table C.5

Two-Step Regression Results Relating Executive Skills to DT (Instances Fluency)

	Model 1 (Covariates predicting DT)		Model 2 (Add ES)	
	Coefficient	β	Coefficient	β
Intercept	5.69		3.36	
Working Memory				0.03 (0.788)
Inhibitory Control				0.09 (0.382)
Shifting				0.03 (0.781)
Covariates				
Multilingualism		0.12 (0.210)		0.09 (0.381)
Processing speed		0.12 (0.271)		0.15 (0.211)
Age		0.07 (0.538)		0.05 (0.633)
Adj. R^2		0.02 (0.146)		0.01 (0.333)
Δ Adj. R^2				-0.01 (0.796)

Note. ES = executive skills; DT = divergent thinking.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Table C.6

Two-Step Regression Results Relating Executive Skills to DT (Instances Originality)

	Model 1 (Covariates predicting DT)		Model 2 (Add ES)	
	Coefficient	β	Coefficient	β
Intercept	0.25		0.28	
Working Memory				0.05 (0.664)
Inhibitory Control				-0.09 (0.389)
Shifting				-0.08 (0.433)
Covariates				
Multilingualism		0.04 (0.670)		0.01 (0.957)
Processing speed		0.20 (0.067)		0.21 (0.087)
Age		0.04 (0.706)		0.06 (0.586)
Adj. R^2		0.03 (0.120)		0.03 (0.190)
Δ Adj. R^2				0.00 (0.646)

Note. ES = executive skills; DT = divergent thinking.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Table C.7
Two-Step Regression Results Relating Executive Skills to DT (Uses Fluency)

	Model 1 (Covariates predicting DT)		Model 2 (Add ES)	
	Coefficient	β	Coefficient	β
Intercept	5.22		5.06	
Working Memory				-0.03 (0.798)
Inhibitory Control				0.01 (0.886)
Shifting				0.00 (0.993)
Covariates				
Multilingualism		0.03 (0.728)		0.02 (0.877)
Processing speed		0.15 (0.174)		0.20 (0.111)
Age		0.01 (0.962)		0.00 (0.979)
Adj. R^2		0.00 (0.418)		-0.02 (0.714)
Δ Adj. R^2				-0.02 (0.994)

Note. ES = executive skills; DT = divergent thinking.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Table C.8
Two-Step Regression Results Relating Executive Skills to DT (Uses Originality)

	Model 1 (Covariates predicting DT)		Model 2 (Add ES)	
	Coefficient	β	Coefficient	β
Intercept	0.95		0.89	
Working Memory				-0.09 (0.415)
Inhibitory Control				0.08 (0.410)
Shifting				-0.08 (0.471)
Covariates				
Multilingualism		0.00 (0.997)		0.03 (0.784)
Processing speed		-0.14 (0.193)		-0.12 (0.339)
Age		-0.06 (0.559)		-0.05 (0.632)
Adj. R^2		0.00 (0.339)		-0.02 (0.616)
Δ Adj. R^2				-0.02 (0.626)

Note. ES = executive skills; DT = divergent thinking.
* $p < .004$ (family-wise error rate based on 12 statistical tests)

Are SES-Creative Cognitive Relations Mediated by or in Interaction With Executive Skills?

Table C.9

Two-Step Regression Examining SES-Executive Skills Interactions Predicting DT (Instances Fluency)

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β	Coefficient	β
Intercept	3.36		4.20	
SES		0.00 (0.999)		0.29 (0.701)
Working Memory		0.03 (0.794)		0.07 (0.563)
Inhibitory Control		0.09 (0.386)		0.08 (0.449)
Shifting		0.03 (0.783)		0.02 (0.837)
SES x Working Memory				0.49 (0.230)
SES x Inhibitory Control				-0.77 (0.195)
SES x Shifting				0.00 (0.973)
Covariates				
Multilingualism		0.09 (0.389)		0.04 (0.702)
Processing speed		0.15 (0.215)		0.15 (0.214)
Age		0.05 (0.635)		0.02 (0.844)
Adj. R^2		0.00 (0.447)		0.01 (0.404)
Δ Adj. R^2				0.01 (0.313)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

Table C.10

Two-Step Regression Examining SES-Executive Skills Interactions Predicting DT (Instances Originality)

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β	Coefficient	β
Intercept	0.33		0.31	
SES		0.13 (0.219)		1.74 (0.020)
Working Memory		0.02 (0.865)		0.04 (0.691)
Inhibitory Control		-0.10 (0.335)		-0.11 (0.250)
Shifting		-0.07 (0.472)		-0.09 (0.391)
SES x Working Memory				-0.29 (0.468)
SES x Inhibitory Control				-1.26 (0.031)
SES x Shifting				-0.12 (0.388)
Covariates				
Multilingualism		-0.01 (0.901)		-0.06 (0.605)
Processing speed		0.20 (0.104)		0.19 (0.120)
Age		0.06 (0.609)		0.08 (0.477)
Adj. R^2		0.03 (0.176)		0.07 (0.096)
Δ Adj. R^2				0.04 (0.119)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

Table C.11

Two-Step Regression Examining SES-Executive Skills Interactions Predicting DT (Uses Fluency)

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β	Coefficient	β
Intercept	6.03		5.81	
SES		0.19 (0.078)		0.79 (0.303)
Working Memory		-0.07 (0.534)		-0.08 (0.511)
Inhibitory Control		0.00 (0.996)		0.00 (0.975)
Shifting		0.01 (0.930)		0.01 (0.922)
SES x Working Memory				-0.34 (0.414)
SES x Inhibitory Control				-0.27 (0.659)
SES x Shifting				-0.01 (0.919)
Covariates				
Multilingualism		-0.01 (0.918)		-0.01 (0.952)
Processing speed		0.18 (0.139)		0.18 (0.154)
Age		-0.01 (0.940)		0.01 (0.935)
Adj. R^2		0.00 (0.483)		-0.02 (0.665)
Δ Adj. R^2				-0.02 (0.848)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

Table C.12

Two-Step Regression Examining SES-Executive Skills Interactions Predicting DT (Uses Originality)

	Model 1 (No Interactions)		Model 2 (Add Interactions)	
	Coefficient	β	Coefficient	β
Intercept	0.90		0.87	
SES		0.03 (0.787)		-0.11 (0.888)
Working Memory		-0.10 (0.396)		-0.08 (0.516)
Inhibitory Control		0.08 (0.427)		0.08 (0.451)
Shifting		-0.07 (0.483)		-0.10 (0.371)
SES x Working Memory				0.25 (0.549)
SES x Inhibitory Control				0.00 (0.996)
SES x Shifting				-0.16 (0.278)
Covariates				
Multilingualism		0.03 (0.817)		0.00 (0.990)
Processing speed		-0.12 (0.333)		-0.12 (0.339)
Age		-0.06 (0.629)		-0.04 (0.707)
Adj. R^2		-0.03 (0.721)		-0.04 (0.805)
Δ Adj. R^2				-0.01 (0.653)

Note. SES = socioeconomic status; DT = divergent thinking.
* $p < .003$ (family-wise error rate based on 20 statistical tests)

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Teaching Assistant, Special Topics in Brain Sciences: Emotion, Memory, and Attention (Mind, Brain, Teaching Graduate Certificate Program, Online), Professor Ranjini JohnBull (Summer 2014)

RESEARCH EXPERIENCE

2015	**Research Assistant, Bob Balfanz, The Pathways from Poverty Consortium, Center for Social Organization of Schools, Johns Hopkins University**
2014 – 2019	**Research Assistant, Amy Shelton, Center for Talented Youth Research Lab, Johns Hopkins University**
2013 – 2019	**Research Assistant, Mariale Hardiman and Ranjini JohnBull, Neuro-Education Initiative, School of Education, Johns Hopkins University**
2013 – 2014	**Research Assistant, Nettie Legters, Mindfulness and Learning Research Symposium, Center for Social Organization of Schools, Johns Hopkins University**

INSTITUTIONAL SERVICE

2016	**Committee Member, School of Education Dean Search, Johns Hopkins University**
2015 – 2016	**Committee Member, School of Education Website Improvement, Johns Hopkins University**
2015 – 2016	**PhD Student Peer Mentor, School of Education, Johns Hopkins University**

2015 – 2016	**PhD Student Committee Chair for Academic and Professional Development, School of Education, Johns Hopkins University**
2015	**Volunteer, Learning and the Brain Conference (World-Class Minds: Improving Education, Teaching and Testing in a Globalized World)**

AWARDS, GRANTS, PROFESSIONAL DEVELOPMENT, AND FELLOWSHIPS

2016 – 2017	**Science for Public Consumption Professional Development Series, Science of Learning Institute, Johns Hopkins University**

PROFESSIONAL AFFLIATIONS

2013 – Present	**American Educational Research Association (AERA), Division C, Learning and Instruction**